The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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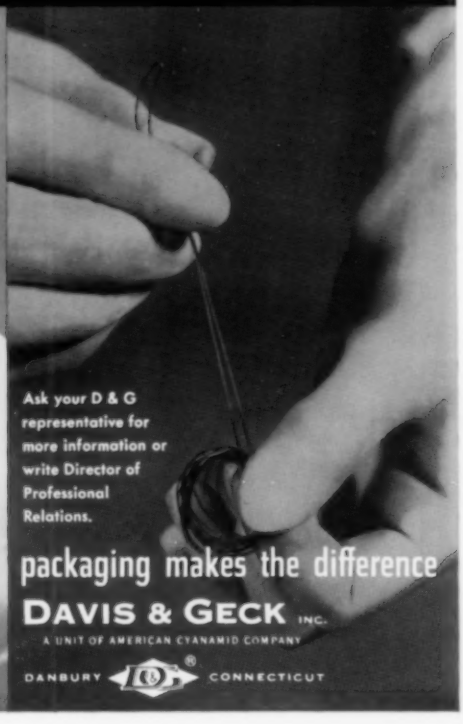

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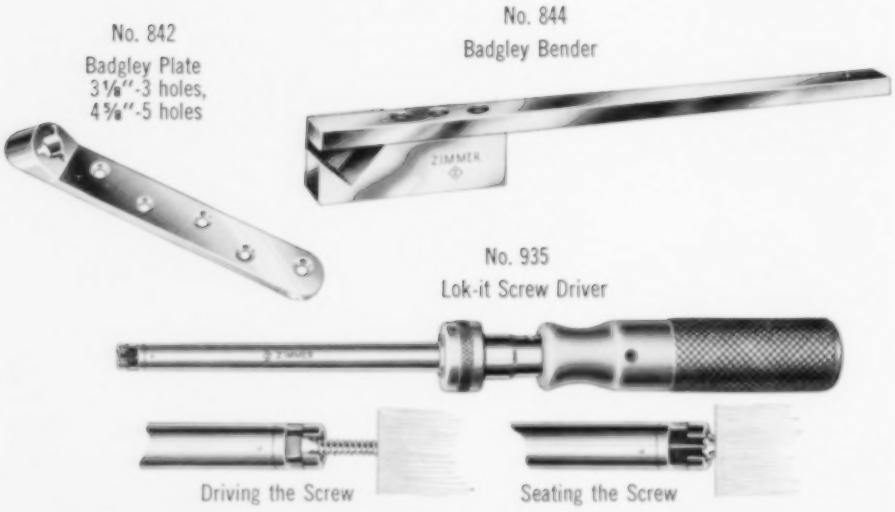

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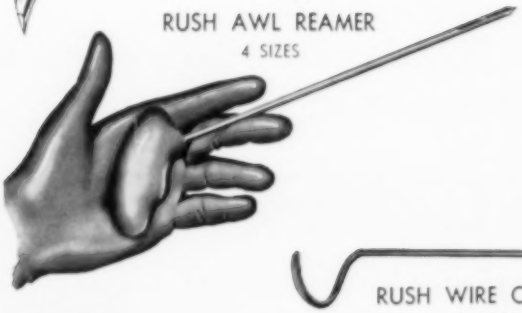

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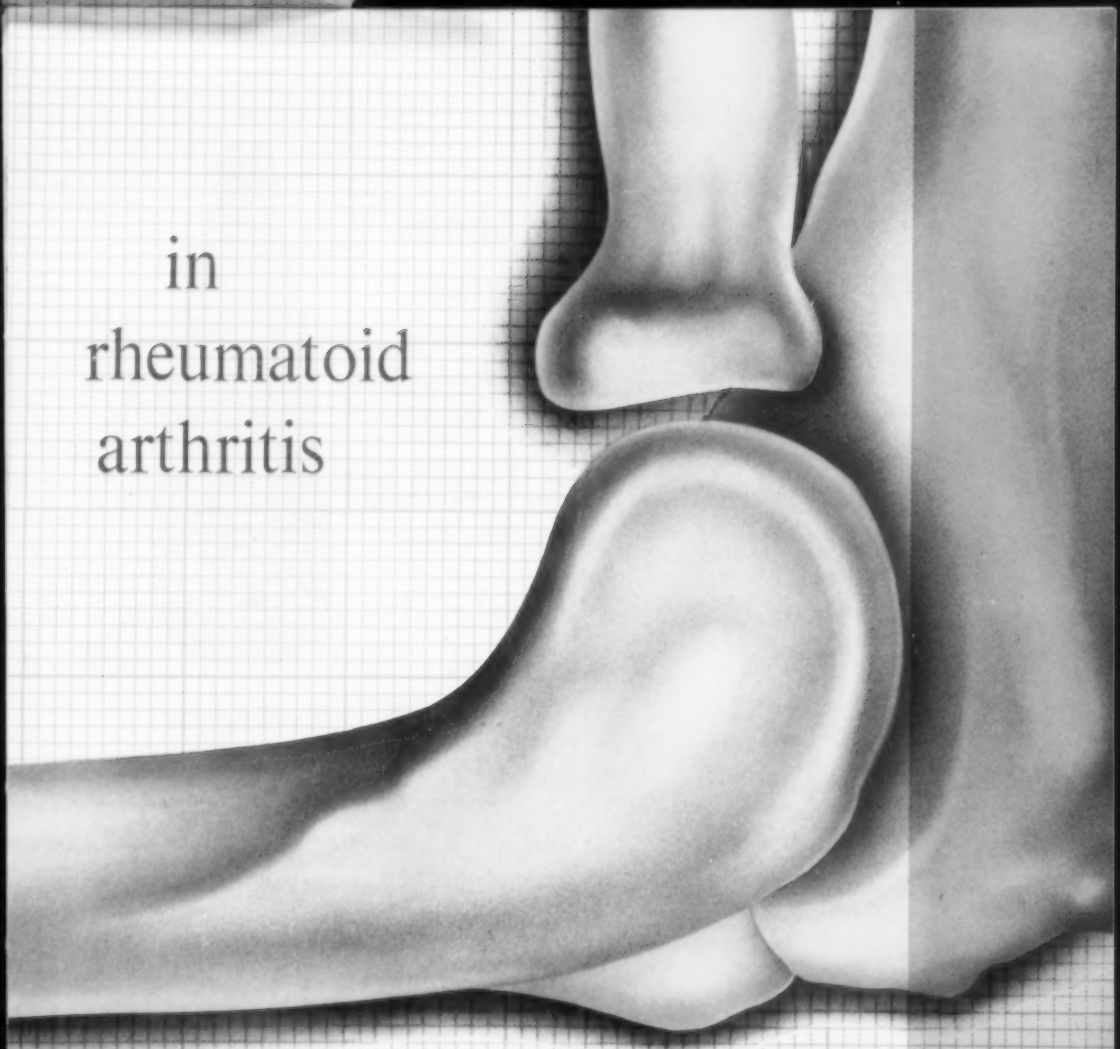

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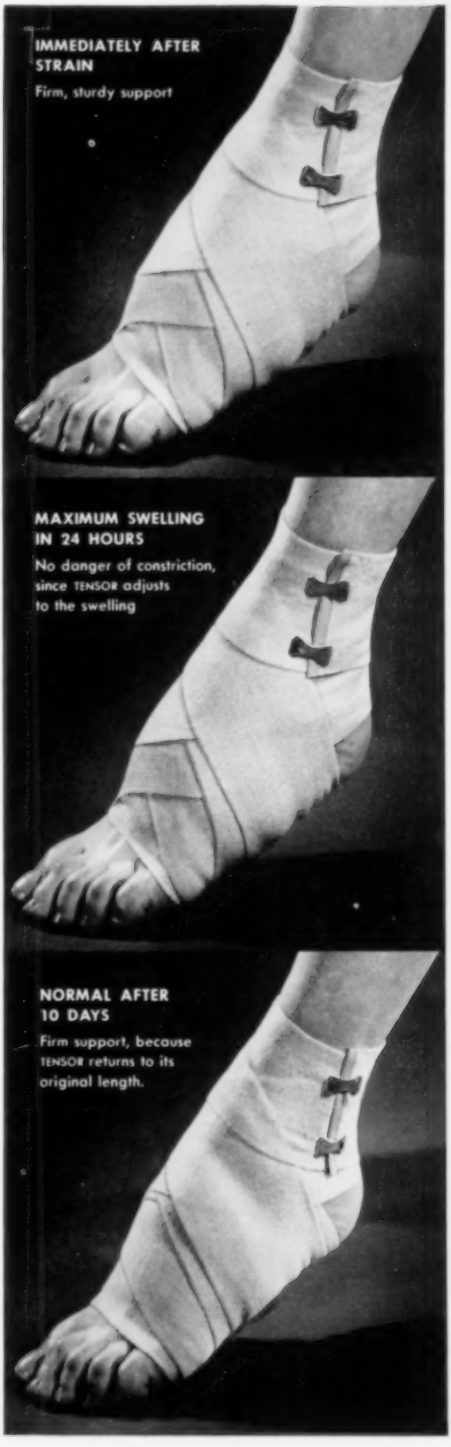
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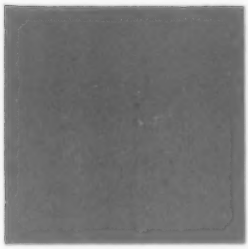

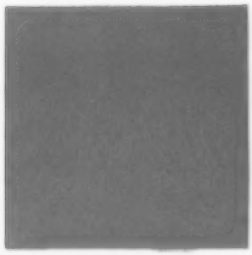

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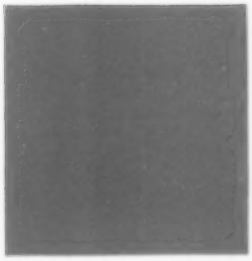

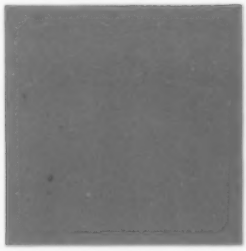

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"Gypsona" Plaster of Paris Bandages are now available in all 48 states through Surgical Supply Dealers. They are made in a wide variety of sizes to fit your every need.

The Hallmark of Quality

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Plaster of Paris Bandages

S&N **SMITH & NEPHEW,** Inc., 137 East 25th Street, New York 10, N.Y.

*Reg. Trade Mark of T. J. Smith & Nephew, Ltd., England

weeks?

months?

years?

Improve the prognosis in fractures with "Premarin" with Methyltestosterone

Healing of fractures is often delayed because impairment of osteoblastic activity due to declining sex hormone function causes the bone matrix to atrophy.

Older patients with fractures, particularly of the hip, respond well to combined estrogen-androgen therapy. The prognosis for bone recalcification is good provided treatment is continued for extended periods.*

*Reifenstein, E. C., Jr., in Harrison, T. R.: Principles of Internal Medicine, ed. 2, New York, The Blakiston Company, Inc., 1954, chap. 98, pp. 702, 703.

"PREMARIN"® with METHYLTESTOSTERONE

Excellent preparation for estrogen-androgen therapy

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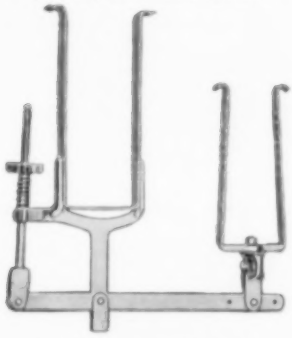
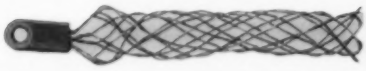
Comminuted intertrochanteric fractures, especially in senile patients?



No. 300—Well-Leg Splint, $35.00

This original and standard Roger Anderson well-leg splint supplies abduction, internal rotation, and fixation. Convalescence is favorable since patient is up in the wheel chair.

Where can I buy finger traps?



No. 504—Finger Traps, $2.25 each

Specify small, medium or large. These are *silver-plated* to permit sterilization without rusting.

How to prevent torsional strain on walking leg casts?
How to keep leg-boot looking trim?

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$2.50 each in lots of 12
Rubber tip replacements, $0.50

Exclusive ball and socket construction. Gives almost normal heel and toe movement in walking on any level. No metal straps to impair X-ray examination of ankle.

How to reduce certain wrist fractures?
How to support arm for cast application?

No. 505—Self-Equalizing Finger Traction Assembly, now only $19.50 complete

Includes pulley assembly and traction plate, sturdy counter-traction strap with buckle, and 3 silver-plated finger traps. Maintains accurate and equal traction on one, two, or three fingers at once.

Are cast knives all alike?

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Here's one that's different. Slip-proof handle even when it's wet. Sharp steel blade easily adjusted to your requirement. Replaceable blade may be sharpened many times since extra cutting length is available.

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EXTRA-FAST-SETTING

For clubfoot, fore-arm and other casts where an extremely fast-setting bandage is desired.

2" x 3 yd. 4" x 5 yd.
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For walking-boots, long-term casts—and wherever maximal strength, minimal weight and effective moisture-resistance are essential.

3" x 3 yd.
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made to merit your professional recommendation

CHILD LIFE "Arch Feature" shoes are so constructed with "built-in" features that certain foot deficiencies can be corrected without need for further wedging. These shoes are also excellently suited for additional modification, as you may prescribe.

A. Supple leather counter molded to embrace and support ankle

B. Broad toe area for full freedom of action

C. Ample width at the insole for the ball of the foot

D. 100% Goodyear Welt Construction

CHILD LIFE "Regulars" are shoes you can recommend with utmost confidence when mothers ask about footwear for their children. In outline above, you see the "specification data" of CHILD LIFE lasts. These shoes also lend themselves well for your prescription work.

In almost every community from coast-to-coast, you'll find a qualified and franchised CHILD LIFE shoe dealer. These men and women have been selected for their knowledge of good fitting practices, and for their specific interest in children's footwear. You'll find them most co-operative and attentive to your prescription work. Please write for full information on CHILD LIFE shoes — on the market since 1924 — and the names of the CHILD LIFE dealers nearest you.

HERBST Shoe Manufacturing Company

Milwaukee 45, Wis.

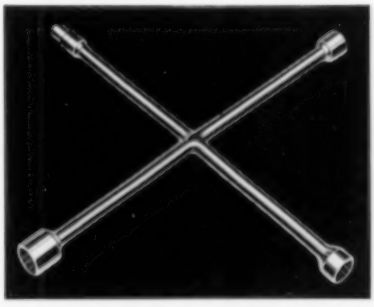
NEW UNIVERSAL WRENCH *by Orthopedic*

COMBINES 4 TOOLS IN ONE!

Fits all the Major Bolt Head Types on Fixation Appliances

This is the tool that received such a great reception at the American Academy of Orthopedic Surgeons Convention in Chicago in February!

This one handy wrench does the work of four . . . has wrench openings for hex bolts of ¼", ⅜", 7/16", and ½" diameter. Handles all the popular types of bolt heads on 195 and 463 Fixation Appliances, including the 96, 96S and 378 nails. Sturdy stainless steel construction, fully cannulated . . . 9" across.



No. 381-U Universal Wrench

For hex bolt head sizes—
¼", ⅜", 7/16", ½".
Shipping Wt. 1½ lbs.

$17.50

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Saves on inventory. No need to stock and handle four sizes of wrenches when one will do. Ask our representative to show you this most versatile of all wrenches.

Order from your surgical supply dealer! Write for free copy of Orthopedic's complete 132 page catalog.

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KLEISTONE knows immediate delivery of orthopaedic appliances is often imperative for the proper correction of ailing or deformed feet.

Our skilled technicians have long experience in filling doctors' special prescriptions quickly, yet with utmost accuracy. For thirty-seven years, KLEISTONE appliances have upheld the highest professional standards. For either ready or custom-made pieces, you can be sure you're recommending the best . . . when you recommend KLEISTONE.

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KLEISTONE RUBBER COMPANY, Inc.
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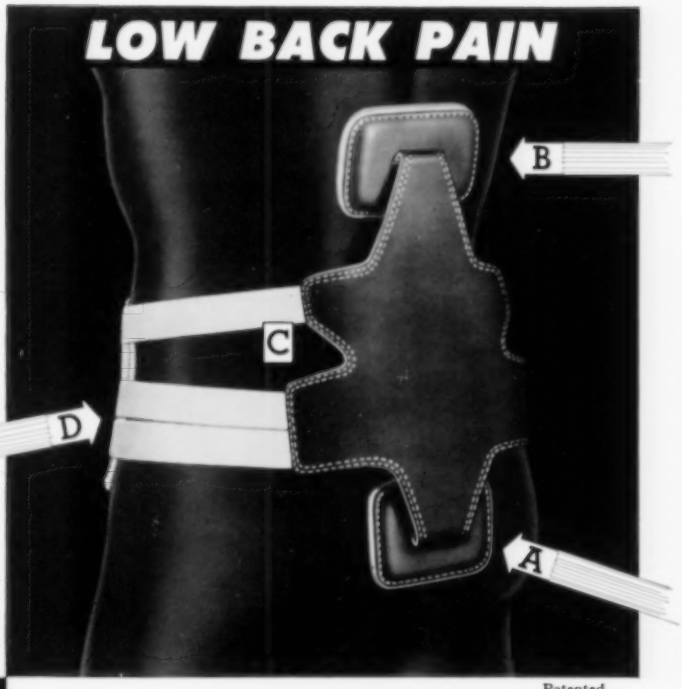
LOW BACK PAIN

Announcing a New Principle of Relief with the Bell Posture Bridge by TRUFORM



Patented

As with all Truform Anatomical Supports, this Bell Posture Bridge is

"Available Only from Your Ethical Appliance Dealer"

Eases facet impingement in the lumbo-sacral area by means of entirely unique 3-point pressure. Observe in the photo these key features:

Exerts Positive Forward Thrust to tilt the pelvis, by direct contact of the lower pressure pad with the posterior surface of the sacrum. (A)

Corrects Posture Defect, even excessive lordotic lumbar curvature . . . with the upper pressure pad acting as a fulcrum. (B)

(C) *Makes No Other Contact* along the back, between the Bridge's two "piers" . . . there is no interference with the positive pressure of the two pads.

(D) *Applies Controlled Counter-Pressure* by means of the tightly-pulled straps.

"Seeing Is Believing" . . . so welcome the Truform fitter in your city, Doctor, when he calls to show you this new Bell Posture Bridge. Only by actually examining and applying this unique support can you fully appreciate its perfect adaptability to the relief of low back pain. Over 500 patients . . . with and without sciatic involvement . . . have already proven the Bell Posture Bridge during its development and clinical evaluation.

Write for "Truform Red Book," the fully illustrated reference catalog of Anatomically Correct Surgical Supports and Surgical Hosiery.

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6 POWERED SURGICAL INSTRUMENTS AT THE SURGEON'S FINGER TIPS WITH Stryker Electro-Surgical Unit

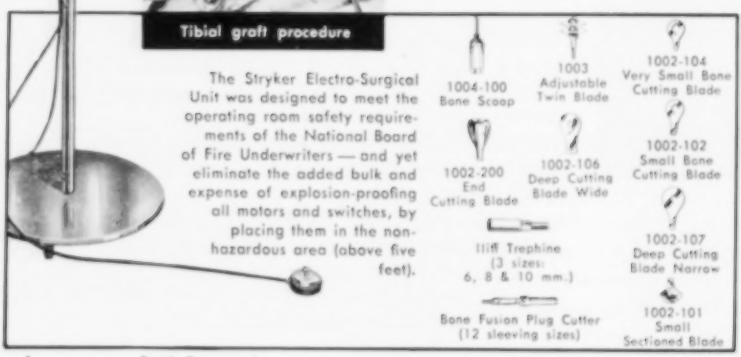
One of a Series — The Stryker Bone Saw Attachment

One Standard and Mayo Table with one power unit gives the surgeon the choice of six powered instruments for many surgical specialties.

Only high speed oscillation makes possible the use of a variety of blades to make every cut the surgeon desires efficiently and without danger to the soft tissues.

Tibial graft procedure

The Stryker Electro-Surgical Unit was designed to meet the operating room safety requirements of the National Board of Fire Underwriters — and yet eliminate the added bulk and expense of explosion-proofing all motors and switches, by placing them in the non-hazardous area (above five feet).


1004-100 Bone Scoop
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results are obtained with STERANE[1]—3 to 5 times more active than hydrocortisone or cortisone.

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capacity is greatly enhanced. "Relief of symptoms is more complete and maintained for longer periods with relatively small doses."[2]

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of minerals and fluids usually remains undisturbed. This proves "especially advantageous in those patients with cardiac failure requiring therapy . . ."[3]

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Supplied: White, 5 mg. oral tablets, bottles of 20 and 100. Pink, 1 mg. oral tablets, bottles of 100. Both deep-scored.

1. Johnston, T. G., and Cazort, A. G.: J. Allergy 27:90, 1956. 2. Schwartz, E.: New York J. Med. 56:570, 1956. 3. Schiller, I. W., et al.: J. Allergy 27:96, 1956.

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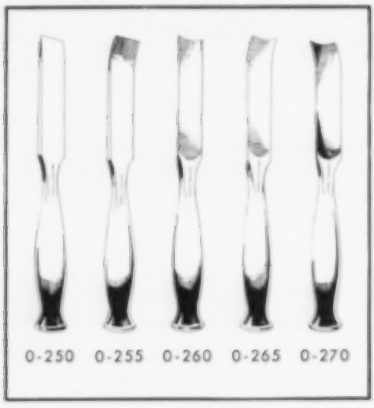
SMITH-PETERSEN OSTEOTOMES and GOUGES



0-250 SMITH-PETERSEN OSTEOTOME—straight, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

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A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

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CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times.
Complete unit may be autoclaved.

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Specify Width of Gouges and Osteotomes When Ordering

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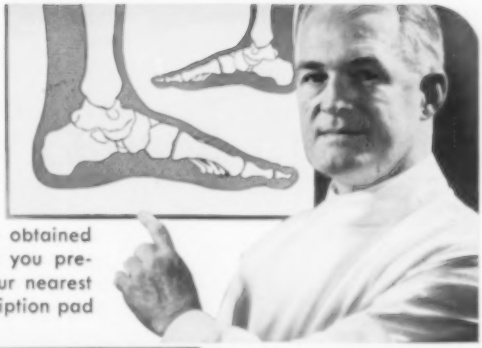
Edwards has the only complete line of Children's Pedic shoes* in the country.

We respectfully submit our knowledge obtained from over 55 years' experience to help you prescribe for your patients. The name of your nearest Edwards dealer, Pedic brochure and prescription pad will be sent upon request.



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For Extreme Cases
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► THOMAS HEEL EXTENDED COUNTER

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REVERSE LAST

STRAIGHT-LAST

Edwards®

* NOTE: The perfect shoes for lateral or medial sole wedging.

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You'll be glad to Prescribe...

Based on the most modern research program

- Long inside counter
- Heavy gauge ribbed steel shank
- Right and left angled heels, long inside
- Patented bottom filler prevents insole lumping

Alden-Pedic

SCIENTIFIC CONSTRUCTION

SHOES

STYLE NO. 66

Alden-Pedic lasts are designed to accommodate your prescribed corrections and insertions. Extreme sizes stocked. Many styles available for men, boys. Top quality only.

Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. To fit the foot shape and accommodate the prescribed corrections is the crux of our program. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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C. H. ALDEN SHOE COMPANY

BROCKTON, MASS.

Custom Bootmakers Since 1884

IT'S *New*... IN VITALLIUM

Vitallium®

MODIFIED INTERTROCHANTERIC NAIL-PLATE COMBINATION

(Similar to Thornton Type)

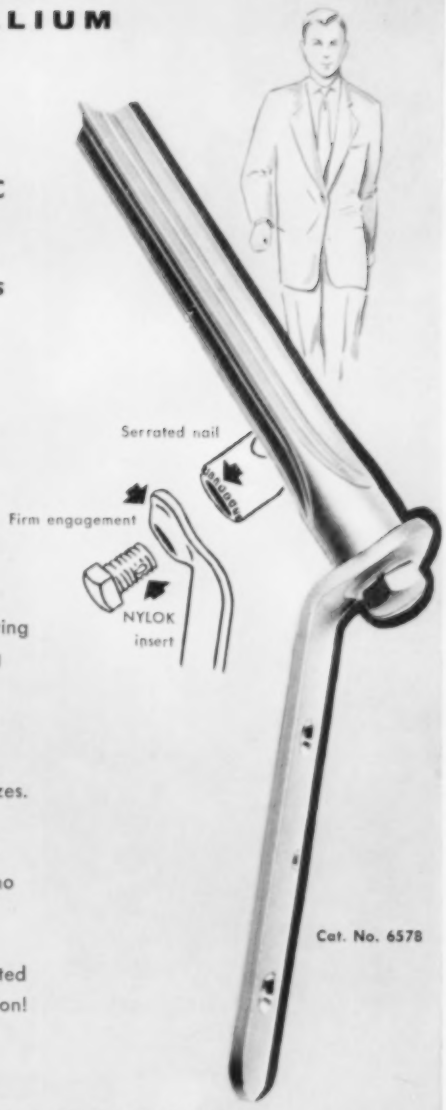
with Many Design Improvements

DIFFERENT • Unlike rigid hip-nailing appliances (McLaughlin and Jewett), this new Vitallium intertrochanteric item may be contoured to suit the case at hand. The plate section is designed to permit contouring to fit anatomical variations of individual femurs, and to compensate for varus or valgus positions.

NEW • Nail and plate are joined by a self-locking bolt and a Nylok* insert, eliminating the difficulty of assembling a two-piece locking screw. Sharp, well-defined serrations on nail and plate assure positive engagement. There can be no slippage.

SIZES • Complete range of plate and nail sizes. Drive shaft and socket wrench also available.

Many requests stimulated the release of this nail-plate combination in Vitallium. There is no electrolytic action between components of any Vitallium multipart appliance. Over 6 million Vitallium surgical appliances have been implanted — without a single authenticated case of corrosion!



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® By Austenal Laboratories, Inc.

* NYLOK — Reg. Tr. Mk. of NYLOK CORP.

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SURGICAL DIVISION

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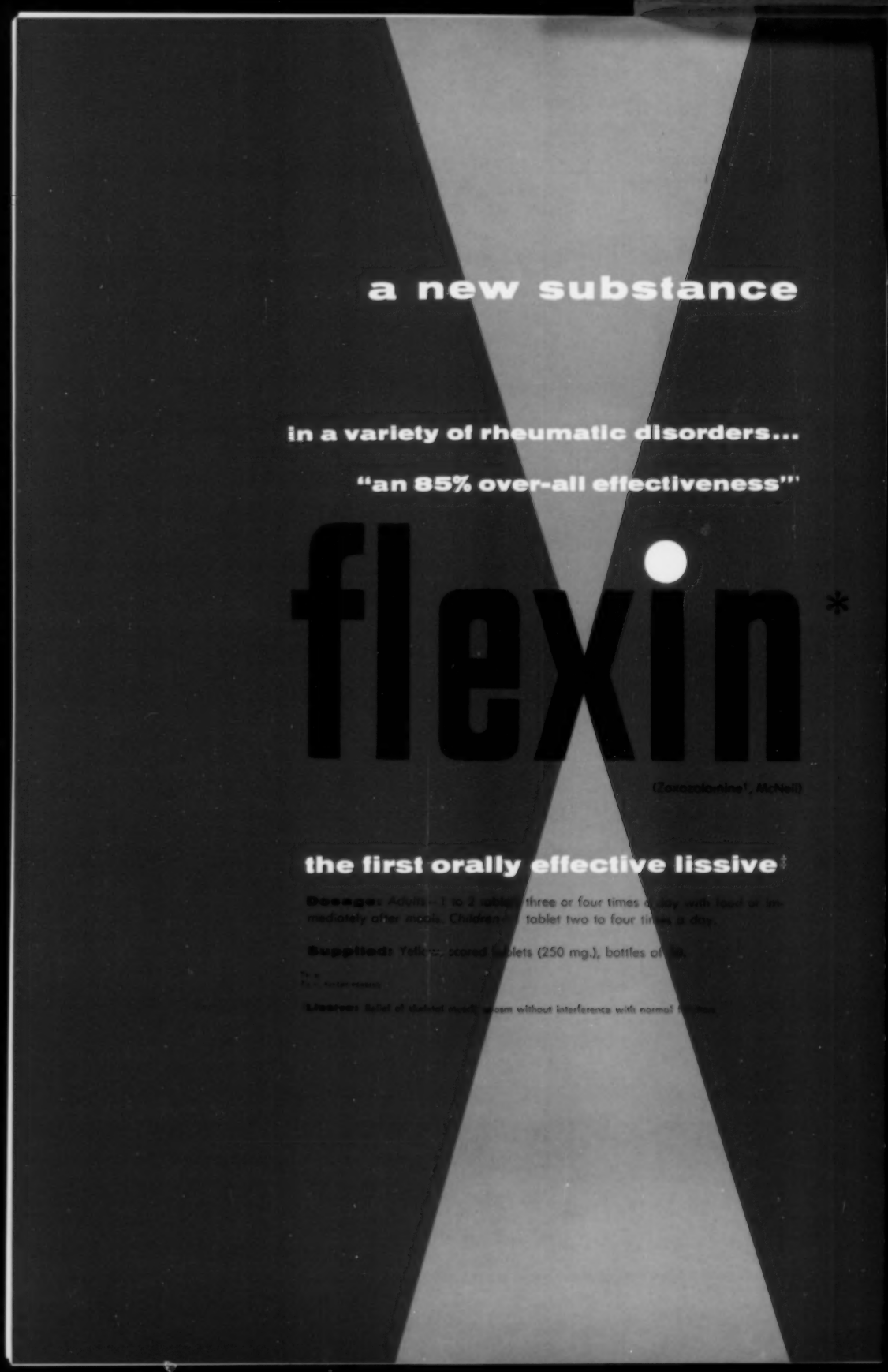
a new substance
in a variety of rheumatic disorders...
"an 85% over-all effectiveness"[1]
flexin*
(Zoxazolamine†, McNeil)
the first orally effective lissive‡

for true spasmolysis of skeletal muscle

Synthesized and characterized by McNeil Laboratories, FLEXIN relieves the disability and pain of skeletal muscle spasm—common denominator of many musculoskeletal and neurological disorders. "Its chief advantages are oral route of administration, long duration of action, and minimal side-effects."

not a mephenesin derivative

FLEXIN provides superior and long-lasting—up to 6 hours—spasmolysis of voluntary muscle in low back syndromes, fibrositis, strains, sprains, and in noninflammatory rheumatic and arthritic disorders. In one preliminary report of 100 patients, FLEXIN demonstrated "...an 85% over-all effectiveness."

Striking results are reported in cerebral palsy. "The administration of zoxazolamine (Flexin) in 28 children, each of whom had spasticity, produced a decrease of muscular tone on passive flexion in every instance."

Other studies indicate that FLEXIN is of value in a highly significant number of patients with multiple sclerosis,[1] as well as in other spinal spasticity states, cerebral vascular lesions and parkinsonism.

(1) Smith, R. T., Knox, R. N., Field, W. F., and Hennessy, T. C.: J.A.M.A. 160:745 (Mar. 3) 1956. (2) Arieti, N.: J.A.M.A. 160:742 (Mar. 3) 1956. (3) Abrahamsen, L. N., and Bland, H. W. (a): J.A.M.A. 160:748 (Mar. 3) 1956. (4) Rodriguez Gomez, M., Varela Rodriguez, A., and Diaz, A. L.: J.A.M.A. 160:752 (Mar. 3) 1956.

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McNEIL

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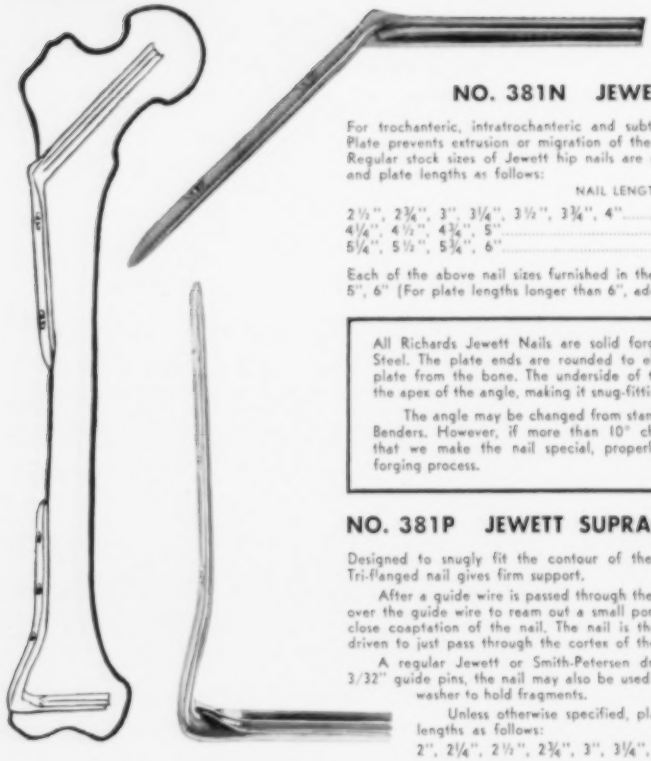
JEWETT NAILS



NO. 381N JEWETT HIP NAIL

For trochanteric, intratrochanteric and subtrochanteric fractures of the femur. Plate prevents extrusion or migration of the Smith-Petersen nail portion. Regular stock sizes of Jewett hip nails are cannulated, angle of 135°, with nail and plate lengths as follows:

NAIL LENGTHS

2½", 2¾", 3", 3¼", 3½", 3¾", 4".....**$12.50** each
4¼", 4½", 4¾", 5".....**13.50** each
5¼", 5½", 5¾", 6".....**14.50** each

Each of the above nail sizes furnished in the following plate lengths: 2", 3", 4", 5", 6" (For plate lengths longer than 6", add $1.25 per inch).

All Richards Jewett Nails are solid forged of one piece SMO Stainless Steel. The plate ends are rounded to eliminate abrupt protrusion of the plate from the bone. The underside of the plate is curved completely to the apex of the angle, making it snug-fitting to the bone.

The angle may be changed from standard by using the No. 414 Jewett Benders. However, if more than 10° change is desired, we recommend that we make the nail special, properly forming the angle in our hot forging process.

NO. 381P JEWETT SUPRACONDYLAR NAIL

Designed to snugly fit the contour of the condyles and shaft of the femur. Tri-flanged nail gives firm support.

After a guide wire is passed through the condyles, a ½" D. reamer is placed over the guide wire to ream out a small portion of the lateral cortex to provide close coaptation of the nail. The nail is then placed over the guide wire and driven to just pass through the cortex of the medial condyle.

A regular Jewett or Smith-Petersen driver may be used. Cannulated for 3/32" guide pins, the nail may also be used in conjunction with a tibia bolt and washer to hold fragments.

Unless otherwise specified, plate length of 6" furnished, with nail lengths as follows:

2", 2¼", 2½", 2¾", 3", 3¼", 3½", 3¾", 4".....**$17.50**

NO. 381S JEWETT SHOULDER NAIL

Indicated for fractures of the upper end of the humerus, mainly in the surgical neck area, or in fractures involving both the anatomical and the surgical neck in some instances.

Also adaptable for rotation osteotomies in the upper end of the femur in the young patient. The nail is not long enough to go into the epiphysis of the head of the femur yet is long enough to give stability with the use of a plaster spica. Nail is removed following complete healing of the bone.

Reduced in all dimensions from regular Jewett Nail. Non-cannulated. Plate length 2"; nail lengths as follows:

1", 1¼", 1½", 1¾".....**$12.50** each

Richards MANUFACTURING CO., MEMPHIS, TENN.

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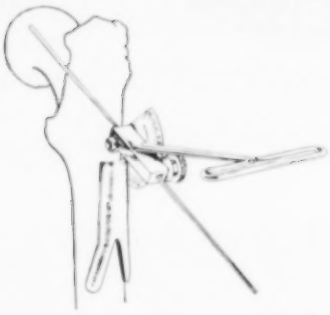
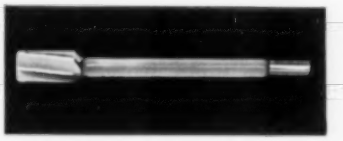


NO. 381GA ADJUSTABLE JEWETT NAIL GUIDE.....$25.00

Stainless Steel. Adjustable with quick positive lock. Protractor reading instantly gives correct angle. Guide pin may be inserted and then its angle measured, or Guide may be used to give pre-determined angle to pin.



NO. 381R REAMER.....$12.00

Cannulated, 1/2" diameter, stainless steel

NO. 414 PAIR JEWETT BENDERS.....$12.00

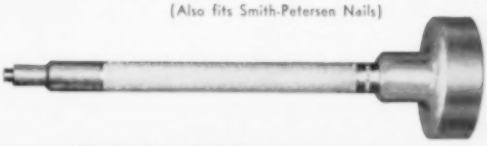
Lightweight yet strong, made of heat treated aluminum alloy. Will not mar or nick SMO stainless bone plates. The nail end of the Jewett Nail is inserted into one end of the benders and the plate is gripped by the sturdy jaw of the other for bending. Also useful in bending and forming bone plates, intramedullary nails, and for twisting heavy plates.

NO. 381G JEWETT NAIL GUIDE.....$10.00

Non-adjustable. For use as a drill jig only, giving an exact angle of 135° to the guide wire. Stainless.

NO. 381D DRIVER, stainless .....**$ 7.00**

(Also fits Smith-Petersen Nails)



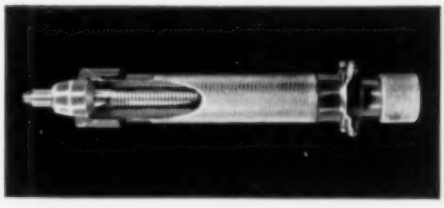
NO. 381DK DRIVER with Aluminum hand driving knob, stainless.....**$10.00**

NO.106A GUIDE PIN, stainless

$ .90 each .....**$9.50** doz.

NO. 106B GUIDE PIN, Calibrated, stainless

$1.25 each.....**$14.00** doz.

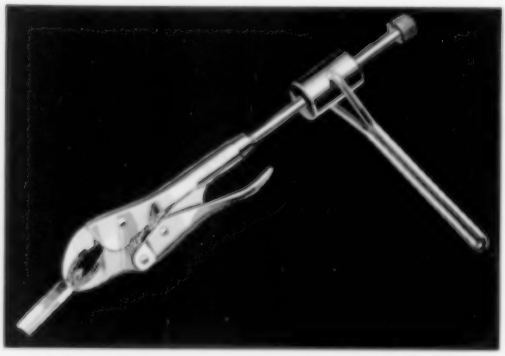


NO. 381E JEWETT NAIL EXTRACTOR, stainless.....**$25.00**

Richards MANUFACTURING CO., MEMPHIS, TENN.

What's New at DePuy for the Orthopedic Surgeon!

McDERMOTT EXTRACTOR



A tremendous amount of extraction power can be obtained with this handy, all purpose extractor. It can be used for intramedullary pins or will extract practically anything that can be held in the vice-grip jaws. Outstanding features of this unit, which facilitate extraction in normally troublesome cases, are exclusive grip-lock construction and extraction hammer. The shaft, extraction hammer and handle portion are of stainless steel. No. 679, $15.00.

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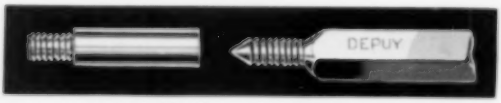

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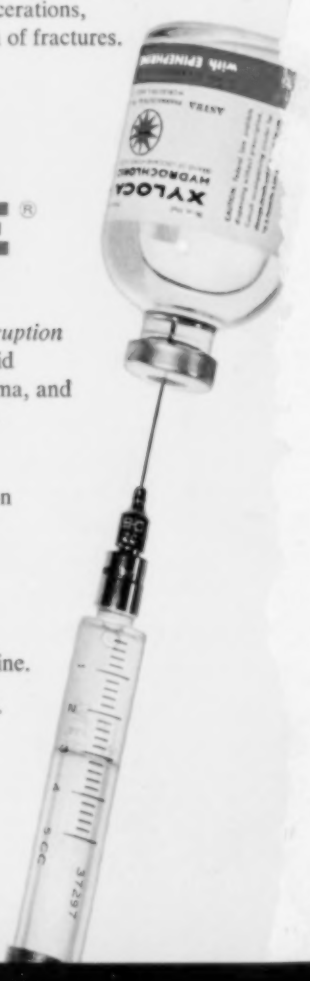

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*Southworth, J. L., and Dabbs, C. H.: Xylocaine: a superior agent for conduction anesthesia, Anesth. & Analg. *32*:159 (May-June) 1953.

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The Journal of
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Soft-Tissue Neoplasms Associated with Congenital Neurofibromatosis *

BY H. R. McCARROLL, M.D., ST. LOUIS, MISSOURI

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Many reports have helped to clarify and to classify the numerous clinical manifestations which may occur in the bizarre disease known as congenital neurofibromatosis. While the skeletal manifestations are perhaps better known to the orthopaedic surgeon, soft-tissue neoplasms are also commonly encountered. Of these, the *café au lait* spot, naevus lateralis, verrucous-type skin hypertrophy, and the neurofibromatous nodule are of little clinical significance. The diffuse soft-tissue hypertrophy, plexiform type of neurofibromatosis, and primary tumors arising in the major nerve components, however, are of major clinical importance. Experience derived from the present series of 136 consecutive cases indicates that soft-tissue neoplasms occurring in this disease may be classified separately under two major headings: primary neurogenic tumors and tumors of other soft-tissue structures. Obviously, the two may occur simultaneously in the same patient; yet, in some patients, tumefaction of major nerve components may exist independently with minimal involvement of adjacent soft-tissue structures.

NEOPLASMS OF SOFT TISSUES OTHER THAN NERVE TISSUE

A classification of neoplasms of soft tissues other than nerve tissue is misleading in some respects since all manifestations in neurofibromatosis result directly or indirectly from involvement of nerve tissue. Many of these lesions, however, such as the neurofibroma and malignant schwannoma are of primary neurogenic origin. The other manifestations, including soft-tissue neoplasms, must be classified as associated lesions induced indirectly by hypertrophy and proliferation within the nerves. In this group may be included the *café au lait* spot, verrucous skin hypertrophy, diffuse soft-tissue hypertrophy, diffuse flat hemangioma, and primary lymphatic changes.

Diffuse hypertrophy of an extremity or part of an extremity frequently commands the attention of the orthopaedic surgeon. These changes in the soft tissues are often accompanied by stimulation of growth of the extremity and by other skeletal manifestations, which have been previously described[9]. When this type of involvement is limited to a portion of one extremity, as is occasionally encountered in one or more digits of the hand, or is manifested solely by hypertrophy of subcutaneous tissues, local excision of the areas of involvement may be of tremendous value and may, at times, control the process (Figs. 1-A through 2-D). In a previous report[9] dealing with the first forty-six cases in this series, a problem of this type involving the index and middle fingers and the adjacent portion of

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1956.

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: P. R. Congenital soft-tissue hypertrophy of right index and middle fingers. (Reproduced from *The Journal of Bone and Joint Surgery*, Fig. 3-A, **32-A:** page 602, 1950.)

Fig. 1-B: Appearance of hand seven years after surgery (four operations) for removal of soft-tissue tumor.

Fig. 1-C: Motion and function remain excellent after seven years.

FIG. 2-A

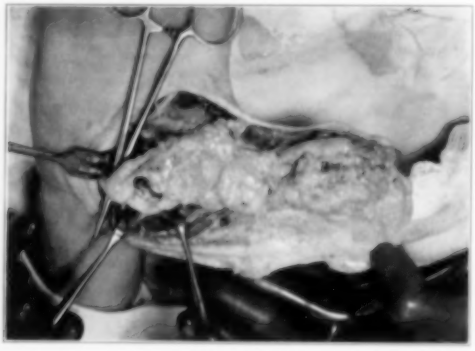

FIG. 2-B

Fig. 2-A: A. H. Soft-tissue hypertrophy of the right thumb and the adjacent thenar eminence.

Fig. 2-B: Soft-tissue hypertrophy consisted of nodular tumors and massive hypertrophy of corresponding digital nerve.

FIG. 2-C

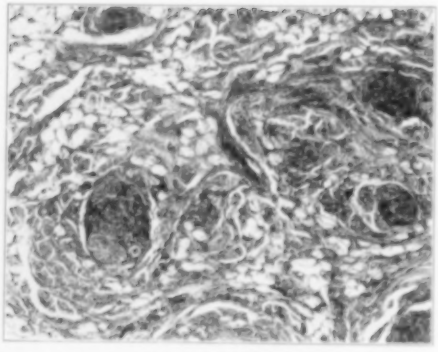

FIG. 2-D

Fig. 2-C: Two years after operation, there was no recurrence of the neoplasm, but the thumb remained unsatisfactory because of the scar. Replacement with a pedicle flap was advised but was refused.

Fig. 2-D: Low-power photomicrograph showing numerous neurofibromatous masses encountered in the hypertrophied soft tissue.

FIG. 3-A

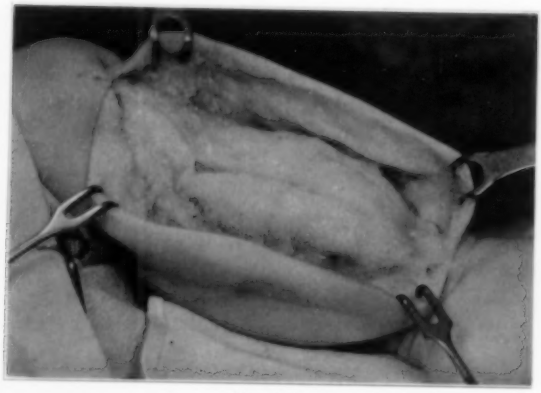

FIG. 3-B

Fig. 3-A: M. B. Diffuse soft-tissue hypertrophy of the thigh and leg. (Reproduced from *The Journal of Bone and Joint Surgery*, Fig. 7-A, **32-A:** page 606, 1950.)

Fig. 3-B: Hypertrophied soft-tissue tumor mass exposed prior to surgical excision. (Reproduced from *The Journal of Bone and Joint Surgery*, Fig. 7-B, **32-A:** page 606, 1950.)

Fig. 3-C: Seven years after operation there was no recurrence of the hypertrophy, no increased discrepancy in the limb length, and the two extremities are quite symmetrical.

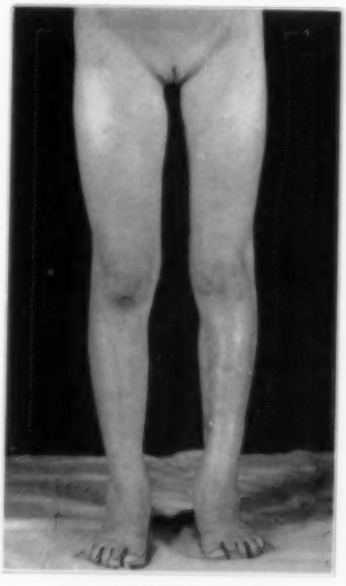

FIG. 3-C

the palm of the right hand was included. The condition (Figs. 1-A, 1-B, and 1-C) was well controlled for seven years with no recurrence of the tumor tissue in the digits. Excellent function of the hand was maintained. A subsequent operation, however, was required for the excision of some residual tumor tissue in the palm of the hand opposite the second and third metacarpal heads. In this patient, the hypertrophied interdigital and digital nerves were removed; their hypertrophy corresponded to the area of soft-tissue tumefaction. There was some residual sensory disturbance over the adjacent surfaces of the involved index and middle fingers; it is surprising how little difficulty this caused.

In another patient reported in the initial series, diffuse soft-tissue hypertrophy was limited to the subcutaneous tissue of the thigh and leg of one extremity (Figs. 3-A, 3-B, and 3-C). In a series of four operations, most of the subcutaneous tissue was removed from the medial and lateral aspects of the leg and thigh. There was no recurrence of this tumor in the seven years in which the patient was followed. There was no impairment of function, no secondary lymphatic changes, and no disturbance of growth. Satisfactory contour of this extremity was maintained (Fig. 3-C).

In other types of involvement, however, the soft-tissue hypertrophy is much more diffuse in character and involves an entire extremity, including the deeper structures, as well as the superficial. In this form associated vascular and lymphatic changes may exist (Figs. 4-A through 5-E). Similar operative procedures for removal of the subcutaneous tissue have been attempted in these patients, but without the same degree of success.

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: E. M. More diffuse type of hypertrophy involving the entire right lower extremity, skeleton as well as soft tissue, with associated diffuse hemangioma.

Fig. 4-B: Posterior view showing the diffuse hypertrophy and the irregular hemangiomatous change.

Fig. 4-C: Appearance of extremity seven years later, after eight operations for excision of the excessive subcutaneous tissue from the leg, thigh, and foot. The second and third rays and the distal phalanx of the great toe were removed to permit the more satisfactory fitting of shoe.

Such involvement cannot be as well controlled, the circumferential hypertrophy of the extremity cannot be entirely corrected, and the secondary lymphatic changes cannot always be prevented. While these extremities can undoubtedly be helped with regional surgery and the disease can be controlled over a period of several years, the majority of patients so affected can be expected to encounter further difficulty. Two patients with such involvement subsequently had repeated attacks of deep-seated cellulitis which may well be the result of some impairment in the deeper circulation.

If this extreme change is limited to a portion of an extremity, amputation might be considered. In many instances, however, the involvement includes not only the entire extremity but the adjacent portion of the trunk; there is no assurance that amputation will entirely obviate the possibility of future difficulty.

PRIMARY NEUROGENIC TUMORS

In the previous report[9], the subcutaneous neurofibromatous nodule was described but only one patient had then been encountered who showed evidence of a primary malignant tumor. The subcutaneous neurofibromatous nodule is characteristic of neurofibromatosis, yet it occurs with relative infrequency. In this series of 136 patients, nodules were encountered in only nine. The nodule represents a true nerve-tissue tumor arising from the Schwann sheath of a small subcutaneous nerve. No instance of malignant change has been reported in these subcutaneous nodules. They are of importance, therefore, only from a cosmetic viewpoint, unless they exist in areas where they may be irritated by clothing.

One type of soft-tissue tumefaction not mentioned in the initial report, since none had been encountered at that time, is elephantiasis neuromatosa (Fig. 6). This may also be considered one of the clinical manifestations of the disease process and has been well described by Stout. He states that it results from thickening of the skin as a result of Schwann-cell proliferation, both within and without the nerves, and that it is, therefore, of primary neurogenic origin. Clinically, elephantiasis neuromatosa consists in a tremendous

FIG. 5-A

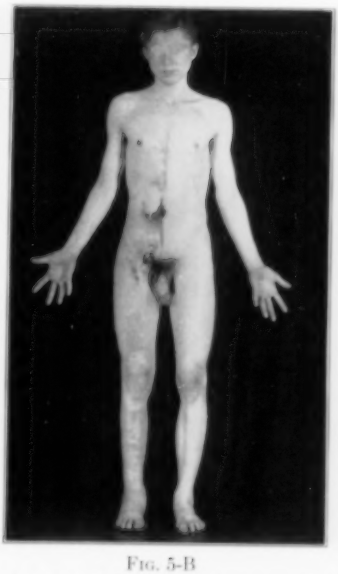

FIG. 5-B

FIG. 5-C

Fig. 5-A: L. B. Diffuse hypertrophy of the right lower extremity with associated lymphoedema. Note the heavy unilateral pigmentation (naevus lateralis). (Reproduced from *The Journal of Bone and Joint Surgery*, Fig. 5-A, **32-A**: page 604, 1950.)

Fig. 5-B: Appearance of extremity one year later after a series of four operations for excision of hypertrophied subcutaneous tissue in right leg and foot.

Fig. 5-C: Six years later, the hypertrophy and lymphoedema have recurred. The recurrence is due primarily to lymphoedema resulting from the diffuse involvement.

FIG. 5-D

FIG. 5-E

Fig. 5-D: The skin, subcutaneous tissue, and fascia were completely excised from the right leg and ankle and were replaced with split-thickness skin grafts. This shows the extremity eight months later when verrucous hypertrophy of skin grafts was taking place.

Fig. 5-E: Extensive verrucous hypertrophy of the skin grafts which crack easily, resulting in lymph drainage. Amputation has been advised but has, thus far, been refused.

FIG. 6

E. F. Elephantiasis neuromatosa consisting of thickened, red, excess skin formation. Note multiple neurofibromata and replacement of nipples with neurofibromata.

excess of skin which hangs in loose folds and which may be red in color. The condition apparently occurs in older age groups; it does not tend to show the verrucous-type skin hypertrophy seen in some patients; and it seems to be of little clinical significance.

Tumefaction, occurring in the deeper, major nerves, commands greater respect and consideration since malignant changes are much more likely to occur. Involvement of major nerve components may occur in conjunction with diffuse hypertrophy of other soft tissues, as mentioned previously. In such instances, the hypertrophy of the major nerve supply to the affected part corresponds to the area of involvement of the other soft tissues (Fig. 2-B). Independent neoplasms may occur in major nerves, however, in the absence of adjacent soft-tissue changes. One such patient with obvious neurofibromatosis in whom a malignant schwannoma had apparently developed in the left twelfth intercostal nerve was described in the initial report. The tumor was excised on the third attempt; the left twelfth rib and some adjacent adherent pleura were also removed. At the time of the initial report, there had been no recurrence of this tumor after a period of three and one-half years. That patient was checked regularly, and on examination after nine years and eight months no evidence of recurrence could be found. He was complaining of some mild indefinite pain in the left flank at that time but complete physical examination, skeletal survey, and roentgenograms of the chest failed to reveal evidence of involvement. Two months later, he reported for a special clinic and stated that, twenty-four hours previously, he was seized with a sudden stabbing pain in the left flank. Further study then revealed a mass completely filling the left flank; intravenous pyelograms revealed marked lateral and inferior displacement of the left kidney (Fig. 7-A). The left flank was explored at operation and a large sac-like tumor mass was encountered which was filled with blood and necrotic tissue (Fig. 7-B). It was removed as completely as possible and microscopic examination again revealed the presence of a malignant schwannoma (Fig. 7-C).

This must be considered as a recurrence of the original malignant tumor since the two were identical in type (compare with Fig. 2-A in the previous report[9]). The recurrence was undoubtedly present at the time of the examination two months prior to the sudden onset of pain and was too small to be identified; it later increased suddenly in size as a result of hemorrhage into the tumor substance. This case may be considered typical of the malignant schwannoma, for such a tumor, incompletely removed, may recur many

FIG. 7-A

FIG. 7-B

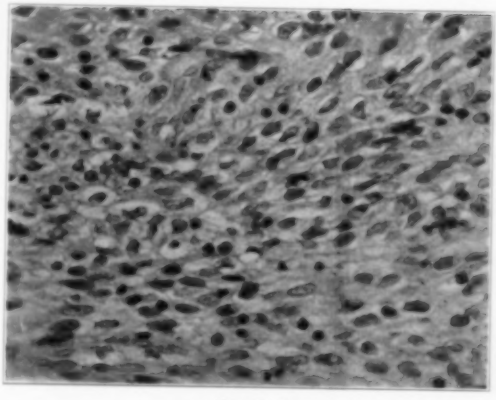

FIG. 7-C

Fig. 7-A: R. M. Roentgenogram showed lateral and inferior displacement of left kidney from retroperitoneal tumor mass, which had recurred nine years and ten months after previous excision of malignant schwannoma. Left twelfth rib was removed at the initial operation.

Fig. 7-B: Sac-like tumor mass filled with hemorrhage and necrotic tissue encountered in retroperitoneal area at operation.

Fig. 7-C: This proved to be a malignant tumor classified as malignant schwannoma. (This case was shown in Figs. 2-A and 2-B, *The Journal of Bone and Joint Surgery*, **32-A**: page 602, 1950.)

years later. The tumor usually recurs locally rather than metastasizing to distant areas as pointed out by Ackerman. Malignant schwannoma is usually found in the patient with all of the clinical manifestations of florid von Recklinghausen's disease.

In still another patient, originally reported (Figs. 8-A, 8-B, and 8-C in the previous report [9]) as having a plexiform-type of neurofibromatosis, additional difficulty has been encountered. Stout states that the plexiform-type of neurofibromatosis may progress continuously up a nerve or group of nerves and may eventually involve the spinal cord. While this patient showed no evidence of progression of the process into the proximal portion of the extremity, there was a marked increase in the local involvement. When this patient was first seen at the age of five years (Fig. 8-A), the condition was limited to one lower extremity below the knee. At that time the tibial nerve was divided and was resutured in the belief that the ingrowth of new nerve fibers would not show the same neurofibromatous change and might result in atrophy of the multiple neurofibromata already present. This, however, was not the case, and there was no demonstrable improvement. The plexiform-type involvement persisted even though local excision of the plexiform area of involvement was attempted two years later. The tumor mass progressed to such an extent that, at the end of ten years, the extremity was so large and so sensitive, even to light touch, that amputation was resorted to. Since there had been no evidence of progression of this tumor mass into the proximal portion of the extremity, the amputation was carried out at the level of the knee. Thorough study of the amputated specimen

revealed diffuse hypertrophy and multiple tumor nodules along the course of the tibial and peroneal nerves (Figs. 8-B and 8-C) with the tumefaction extending proximally in the sciatic nerve to the upper border of the soft-tissue hypertrophy. The muscles of the calf had, by this time, been almost completely replaced with tumor tissue (Fig. 8-B); microscopic examination of the area and of the neoplasms in the major nerves revealed no evidence of a malignant condition.

In another patient (Figs. 9-A through 9-E) with severe skin sensitivity from soft-tissue tumefaction in one leg, enormous hypertrophy of the tibial, medial sural cutaneous, common peroneal, and superficial peroneal nerves was encountered (Fig. 9-B). Again, the involvement of the major nerves corresponded to the area of soft-tissue hypertrophy (Fig. 9-D). An attempt was made first to excise the involved nerves, but multiple smaller tumors were encountered which filled the entire popliteal space (Fig. 9-C). In the attempt to excise these, the popliteal vessels were irreparably damaged and amputation of the extremity was necessary ten days later. No evidence of malignant growth was found in these hypertrophied nerves which had been almost completely replaced by benign neurofibromatous nodules (Fig. 9-E). In the light of the subsequent development of the condition in other similar patients, it is possible that the need for amputation of this extremity may have represented a blessing in disguise.

Multiple bulbous tumors may also occur along the course of major peripheral nerves, and spindle-shaped tumor masses may replace their smaller divisions (Fig. 10-A). Should the latter occur, excision of the tumor and the involved nerve component is indicated; should the former occur, they may be distributed along the course of a major nerve without replacing it initially. In such an instance, an attempt should be made to excise the tumors at the initial operation. Frequently, however, they are far too numerous to be removed except by excision of the entire nerve. All such tumors should be thoroughly studied microscopically for evidence of malignant change and the importance of obtaining the aid of a surgical pathologist who is expert in this field cannot be overemphasized.

FIG. 8-A

FIG. 8-B

FIG. 8-C

Fig. 8-A: J. R. Hypertrophy of right lower extremity extending proximally to lower third of thigh. Soft tissue enlargement consisted of plexiform type of neurofibromatosis. (Reproduced from *The Journal of Bone and Joint Surgery*, Fig. 8-A, **32-A**: page 607, 1950.)

Fig. 8-B: Dissection of the extremity, which was amputated ten years later, revealed a nodular hypertrophied tibial nerve and replacement of the calf group of muscles with tumor tissue.

Fig. 8-C: Multiple nodules along the course of the peroneal nerve and its divisions.

FIG. 9-A

Fig. 9-A: D. B. Hypertrophy right lower extremity ending in upper pole of popliteal space. The involved portion of this extremity was extremely sensitive to even light touch.

FIG. 9-B

Fig. 9-B: On exploration of the posterior aspect of this leg, massive hypertrophy of tibial and peroneal nerves was encountered; tortuous hypertrophied superficial division represents medial sural cutaneous nerve.

FIG. 9-C

Fig. 9-C: On retracting major nerves, popliteal space was found to be filled with multiple neurofibromatous nodules. On attempting to remove these the blood supply was irreparably damaged, necessitating amputation ten days later.

FIG. 9-D

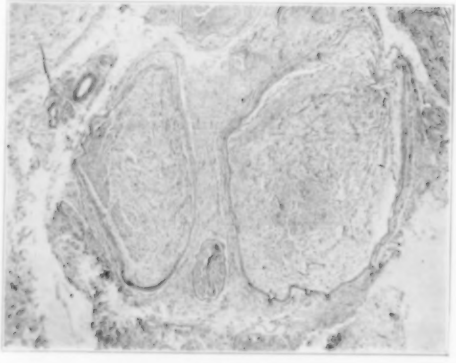

FIG. 9-E

Fig. 9-D: The tibial and medial sural cutaneous nerves were excised at the operation. This shows tibial nerve dissected inferiorly to the medial malleolus and the tumefaction of the nerve disappears at this level. This corresponded to the patient's soft-tissue hypertrophy.

Fig. 9-E: Plexiform neurofibromatosis replacing the normal nerve structures. There was no evidence of malignancy.

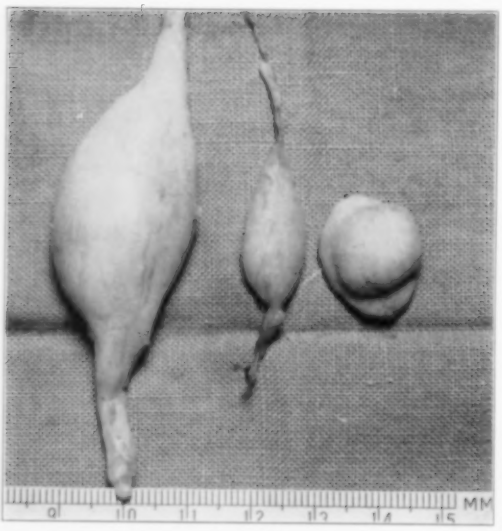

FIG. 10-A

Fig. 10-A: J. P. Two spindle-shaped neurofibromata completely replacing superficial cutaneous nerve branches and one subcutaneous neurofibromatous nodule. These represent benign lesions, occurring in a patient with diffuse neurofibromatosis.

Evidence of early malignant change in a neurofibromatous tumor may, at the onset, be very subtle. The presence of malignant change, as stated by Ackerman, may be manifested solely by slight increased cellularity and changes within the nuclei. The diagnosis based on tissue studies must be compatible with the clinical history and findings.

If there is evidence of malignant schwannoma, more radical therapy should be seriously considered. While these tumors may vary considerably in the degree of malignant growth, further difficulty is often encountered, and, if the tumor recurs, amputation of the involved extremity should be seriously considered. It should be remembered, however, that, in patients with a diffuse involvement of the entire body, it is possible that primary independent malignant tumors may arise in multiple areas simultaneously. A differentiation between this type of involvement and metastases from a single focus may be extremely difficult. If, however, the chest shows no evidence of metastatic involvement, it seems reasonable to assume that these may represent primary independent manifestations of the systemic disease.

Once initial malignant change has occurred in a preexisting neurofibroma, malignant tumors may appear in rapid succession in other parts of the body. In a problem of this type in a boy twenty-one years of age (Figs. 10-A through 10-I) with diffuse neurofibromatosis, the initial malignant schwannoma (Fig. 10-B) occurred in the form of an encapsulated tumor mass adjacent to the proximal portion of the left sciatic nerve. Examination shortly afterward revealed the presence of localized, deep-seated soft-tissue tumor masses

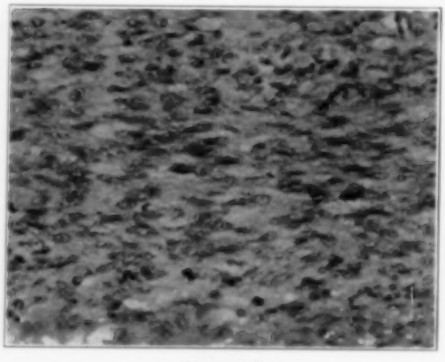

FIG. 10-B

FIG. 10-C

Fig. 10-B: Malignant schwannoma occurring in tumor mass adjacent to proximal portion of right sciatic nerve.

Fig. 10-C: Eight months later another tumor mass had developed in the posterior portion of the right thigh near its midpoint. Excision revealed similar malignant schwannoma arising as shown from motor branch of semitendinosus muscle.

FIG. 10-D

Longitudinal section of this motor nerve shows benign hypertrophy and increase in vascularity before it expands into the area of malignancy.

FIG. 10-E

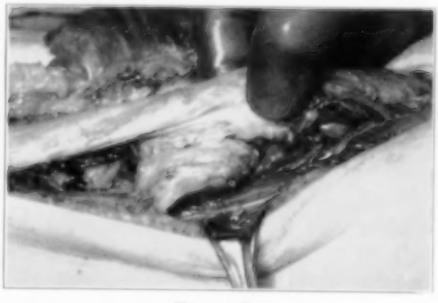

FIG. 10-F

Fig. 10-E: After fourteen months the tumor had recurred further distally in this thigh in the remaining portion of the inner hamstring muscles. This tumor as shown was nodular in character. Amputation of this extremity was advised repeatedly but refused.

Fig. 10-F: After sixteen months the tumor had again recurred and on this occasion completely surrounded the hypertrophied nodular sciatic nerve as shown.

in three extremities. The tumor masses were removed, but each was found to be a benign neurofibroma (Fig. 10-A). Shortly thereafter, there was a recurrent tumor mass on the posterior aspect of the thigh distal to the point where the malignant schwannoma had been originally removed. Excision of this mass showed it to be adjacent to the sciatic nerve and arising in a motor nerve branch to the semitendinosus muscle (Fig. 10-C), but the trunk of the sciatic nerve was apparently not involved. This proved to be a malignant schwannoma (Fig. 10-D), and amputation of the extremity was advised. Amputation was consistently refused in spite of the fact that two months later another malignant schwannoma recurred in the thigh and, on exploration, was found to encircle more completely the sciatic nerve than the two previous tumors (Fig. 10-E). The tumor again recurred and at the fourth operation the sciatic nerve was found to be completely surrounded and identification of the major nerve structures was difficult (Fig. 10-F). Within three weeks following this operation, a tumor mass developed in the right axilla (Fig. 10-G) and another in the right side of the pelvis (Fig. 10-H). Roentgenograms revealed extensive destruction of the right innominate bone. Shortly thereafter there was again a recurrent tumor mass on the posterior aspect of the right thigh (Fig. 10-I). It was now obvious that amputation of the originally involved extremity would be of no value. Since the roentgenograms of the chest had remained consistently clear, it seemed likely that the tumor in the right axilla and the tumor involving the right side of the pelvis represented primary

FIG. 10-G

FIG. 10-H

FIG. 10-I

Fig. 10-G: Eighteen months after the original surgery a rapidly expanding tumor appeared in the right axilla.

Fig. 10-H: At the same time a rapidly expanding tumor developed in the right side of the pelvis with destruction of the innominate bone. These photographs were taken twenty-one months after the initial operation.

Fig. 10-I: Recurrent tumor mass on posterior aspect of right thigh at this time. Patient died twenty-two months after the initial operation.

independent lesions in major nerve trunks of these areas. The patient experienced a rapid downhill course and expired six months after the last operation and twenty-two months after the initial diagnosis of malignant schwannoma had been made.

In another patient with some plexiform hypertrophy about the ankle and lower portion of the leg, there was extreme diffuse sensitivity to pressure over the ankle and lower portion of the leg and over the posterolateral aspect of the knee. The maximum

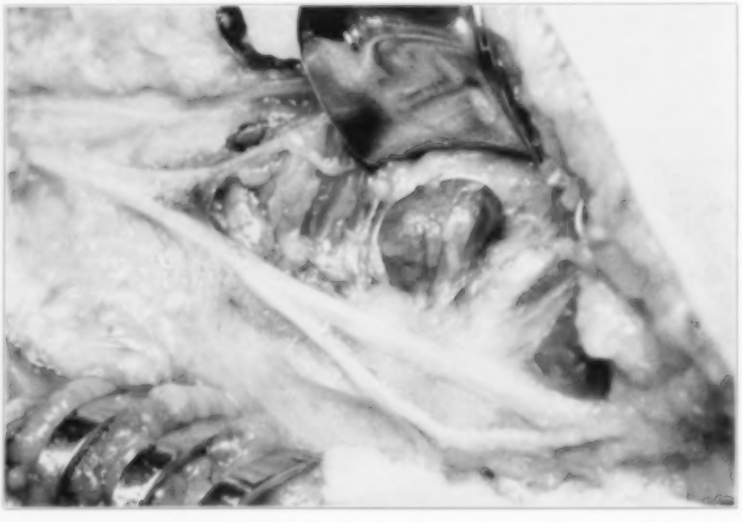

FIG. 11

J. B. Glomus tumor posterior to the lateral femoral condyle attached to capsule of knee joint. Note the peroneal nerve appears normal. This occurred in a patient with neurofibromatosis and superficial plexiform change in the distal portion of this extremity. The presence of the glomus tumor is probably coincidental.

TABLE I

CLINICAL MANIFESTATIONS OF CONGENITAL NEUROFIBROMATOSIS IN 136 CASES

Type of Involvement	Clinical Manifestations	No. of Cases
Cutaneous	*Café au lait* spots	115
	Naevus lateralis	2
	Verrucous skin hypertrophy	4
Subcutaneous	Diffuse soft-tissue hypertrophy	30
Skeletal	Scoliosis	73
	Bone hypertrophy	24
	Bone cysts	3
	Congenital shortening of lower extremity	10
	Congenital pseudarthrosis of tibia	5
	Spondylolisthesis	5
	Prespondylolisthesis	3
	Melorheostosis	3
	Fibrous dysplasia	1
Vascular	Diffuse flat hemangioma	9
	Plexiform dilatation of veins	2
	Thick-walled veins in hypertrophied subcutaneous tissue	13
Lymphatic	Oedema of hypertrophied extremity	5
	Dilated lymph spaces	4
Primary neurogenic	Neurofibromatous nodules	9
	Hypertrophy of major nerve trunks	3
	Malignant schwannoma	3
	Plexiform neurofibromatosis	5
	Elephantiasis neuromatosa	1

point of tenderness was located posterior to the lateral femoral condyle. It was thought that this represented a neurofibromatous change either in the common peroneal or superficial peroneal nerve. At operation, however, the major nerves were found to be normal in all respects and on reflection of the lateral head of the gastrocnemius a large glomus tumor was found adjacent to the capsule of the knee joint (Fig. 11). Removal of the glomus tumor relieved the patient of all symptoms although as a precautionary measure the area of plexiform neurofibromatosis was also excised on the lateral aspect of the ankle. Glomus tumors are encountered with relative frequency and, since their association with congenital neurofibromatosis has never been previously reported, this finding may be entirely coincidental.

DISCUSSION

It is obvious from any study of a large series of patients with the clinical manifestations of congenital neurofibromatosis that tumefaction of major nerve structures is occasionally encountered. These, at times, exist as diffuse hypertrophy of major nerves in which they are largely replaced by a mass of neurofibromatous tissue. Isolated benign tumors may also occur adjacent to major nerves or, at times, may completely replace the smaller peripheral-nerve branches. Secondary malignant changes may take place in these benign tumors. It seems advisable, therefore, that these should be completely excised, if possible, once their presence has been established. When malignant changes have taken

place in these tumors, more radical surgery is required. The frequency with which these malignant tumors occur cannot be stated with accuracy. Hosoi has estimated that in 13 per cent of all patients with von Recklinghausen's disease malignant tumors develop. On the basis of our study, this would seem to be far too high. In this series of 136 patients we have proved the presence of malignant tumors in only three patients. It must be remembered, however, that malignant schwannoma has been reported more frequently in the mediastinum and retroperitoneal area and that such findings seldom come to the attention of the orthopaedic surgeon.

In a previous report dealing with the initial forty-six cases in this series, the clinical manifestations of neurofibromatosis were classified under five major headings: cutaneous, subcutaneous, skeletal, vascular, and lymphatic. It is now obvious that a sixth classification should also be included: primary neurogenic involvement. The incidence of each classification in this series of 136 cases is shown in Table I. This study would seem to support the statement of Stout that lesions in von Recklinghausen's disease are of two varieties: (1) those resulting from proliferation of sheath cells and nerve fibers and producing primary nerve tumors, either benign or malignant, and (2) the associated or secondary lesions induced directly or indirectly by the neurofibromatous proliferations in the cutaneous, subcutaneous, skeletal, vascular, and lymphatic manifestations.

SUMMARY

Soft-tissue neoplasms are not infrequently encountered as one of the clinical manifestations of congenital neurofibromatosis. In those patients in whom diffuse soft-tissue hypertrophy remains relatively isolated and in whom it is limited to a portion of one extremity, radical excision of the hypertrophied subcutaneous tissue and the involved peripheral nerves, when such are encountered, may control the progress of the disease (Figs. 1-A through 3-C). In many patients, however, with a more diffuse type of involvement covering an entire extremity or a greater portion of the body, in whom the deeper soft-tissue structures, as well as the subcutaneous tissue, are involved, regional surgery may not prevent the progression of the process. In many instances, diffuse flat hemangiomatous changes may be encountered and primary or secondary lymphatic involvement may also have occurred. Primary tumors may occur in major nerve structures and these may be benign or malignant in type.

NOTE: The author wishes to express his gratitude to L. V. Ackerman, M.D. for many helpful suggestions in this study and to Mr. Cramer Lewis for the photographic work.

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DISCUSSION

Dr. Carroll B. Larsen, Iowa City, Iowa: We cannot help but be impressed by the tremendous clinical experience of Dr. McCarroll with neurofibromatosis. Dr. McCarroll has hinted that in von Recklinghausen's disease, the lesions are of more than one variety. If we could, for a moment, rationalize the existence of all the lesions on a single basis, it might then change our thinking as regards this disease.

[Three slides illustrating tuberous sclerosis were shown to indicate that there is undifferentiated embryonal tissue present in a skin appendage. In the first slide, it was shown that the tissue cells in the depth of the skin appendage were quite different from the remainder of the cells. In the second slide, a section was shown from the kidney of the same patient. Part of the kidney was forming its proper tissue, the remainder was not. Here was an embryonal-tissue arrest that probably had its origin in embryonal life. The third slide showed section from the brain of the same patient. Again undifferentiated tissue was seen. The undifferentiated portion of the tissue showed multiple malignant changes in very many areas.] Tuberous sclerosis is a multi-varied disease involving such tissues as I have shown. Dr. Moulton has written on the hamartial nature of the tuberous sclerosis complex and its bearing on tumors. He has pointed out the similarity of the microscopic picture of the disease in whichever organ it appears. He has elaborated on the theme that the disease is the result of a widespread and disseminated blastomatous agency which is active in embryonal life. This results, then, in a retardation of cell differentiation. Hence, the congenital lesions homologous with hamaratiosis. If we take the term, embryonal rest, and merely restate it as hamartial malformation, the entire concept of transition of a malformed tissue from benign to malignant tissue can be simplified. This concept could also explain the incidence of the malignant changes as well as the multiplicity of lesions that we see in neurofibromatosis. What evidence do we have that this might be so? [Slides were shown illustrating microscopic similarities. The first was a section from a tumor which had been diagnosed as a hamartoma; this had no relationship to neurofibromatosis whatsoever. Yet, in it was the embryonal connective tissue, a circular formation which we will call a Verocay body or an abortive attempt at formation of nerve tissue. Another slide showed a similar attempt to form a Verocay body; this section had been taken from the subcutaneous tissue of a patient with generalized neurofibromatosis. The third slide showed a tumor removed from the back of the knee joint; this was one of two tumors that occurred, so far as we could tell, in this particular patient. The fourth slide showed a microscopic section of the tumor. In it was seen the embryonal-tissue formation, a Verocay body that appears similar to the others shown. This was from a patient with lymphangiomatosis; the case has already been described by Dr. McCarroll. This slide again showed the similarity in tissues, with the exception that in this there were larger lymphatic spaces, and an abortive attempt at the formation of the Verocay body.] There is, thus, some similarity microscopically between all of these lesions. When we know more about the influences of embryologic development, we may eventually visualize the entire picture of neurofibromatosis from the point of view of etiology. We may go so far as to include Maffucci's syndrome. This, as a matter of fact, could be just another stage in the advance of the disorganization of embryonal tissues which may be the basis of neurofibromatosis.

Dr. William T. Green, Boston, Massachusetts: Neurofibromatosis is a bizarre disease—its manifestations are most variable and so many of them not well understood. One might think that since the neurolemma cell or Schwann cell is involved that it would affect only tissues of ectodermal origin, but its expressions are much greater than this. It affects mesenchymal tissues; and bone, for example, shows many expressions of neurofibromatosis. These include localized lesions of bone of destructive type, hypertrophy and overgrowth of bone, erosive and sclerotic lesions, structural scoliosis, sinuous bowing of the tibia, and pseudarthrosis of the tibia. Some of these are associated with soft-tissue tumors; others are not. The increased incidence of congenital anomalies, the diffuse hypertrophy of tissues other than neurofibroma, and the mechanism of many of the abnormalities of bone are hard to understand.

The fact that more than one germ layer is affected in neurofibromatosis shows that the abnormality must arise at a very early stage of development, or indeed that the ectodermal neural element may be a factor in the evolution of abnormalities affecting many areas.

This is a remarkably large group of cases that Dr. McCarroll has been able to observe. We have in a smaller series about one third as large when last reviewed, an incidence of soft-tissue involvement and tumors

(Continued on page 900)

Avascular Necrosis Involving Articular Surfaces *

BY W. E. GALLIE, M.D., TORONTO, ONTARIO, CANADA

In the face of the present enthusiasm for the quick restoration of function in diseased and injured joints by the introduction of various kinds of prostheses, one hesitates to be critical of the brilliant immediate results that are sometimes obtained. Yet before being converted completely to the new replacement therapy, it might be well to reconsider for a moment just what one can expect from dependence on the natural processes of repair.

I shall introduce my subject by the presentation of a simple case report:

On March 4, 1946, a man, twenty-one years old, stepped into a two-foot hole and violently wrenched his knee. The roentgenogram made a few days later showed that a large piece of the weight-bearing surface

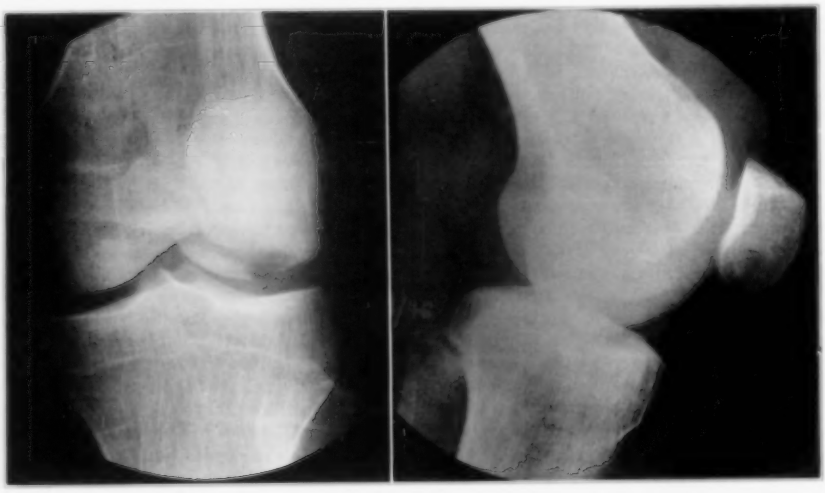

FIG. 1-A

of the outer condyle of the femur had been avulsed (Fig. 1-A). On March 14, the knee was opened, the blood was evacuated, and the loose piece of the femur was extracted for examination. It was about the size of a silver dollar, a third of an inch thick at its middle, and shelved off to a thin edge at its circumference. It was then fitted back into its bed, was pressed solidly home with a blunt instrument, and was fastened in place with two beef-bone pins inserted obliquely to one another. These pins were counter-sunk to about an eighth of an inch below the articular surface (Fig. 1-B).

The subsequent history of this patient has been entirely satisfactory. He made an uneventful recovery from the operation, and, in a few months he was back at work without disability of any kind. Roentgenograms made at yearly intervals over the past ten years showed that the avulsed bone healed accurately in its bed and that there has been no collapse of bone, no thinning of articular cartilage, and no evidence of traumatic osteo-arthritis. Physical examination showed the knee to be perfectly normal (Fig. 1-C).

Experiences such as this, which are quite common, leave one wondering why, if complete restoration of joint surfaces occurs in some cases, it fails to take place in others. Why do some authorities recommend that loose pieces of articular surfaces be removed rather than be replaced? The answer is, of course, that there must be some basic differences, either in the pathological anatomy of the injury or in the treatment, which determine the ultimate result.

* Read at the Annual Meeting of The American Orthopaedic Association, Bretton Woods, New Hampshire, June 7, 1954. Submitted for publication February 27, 1956.

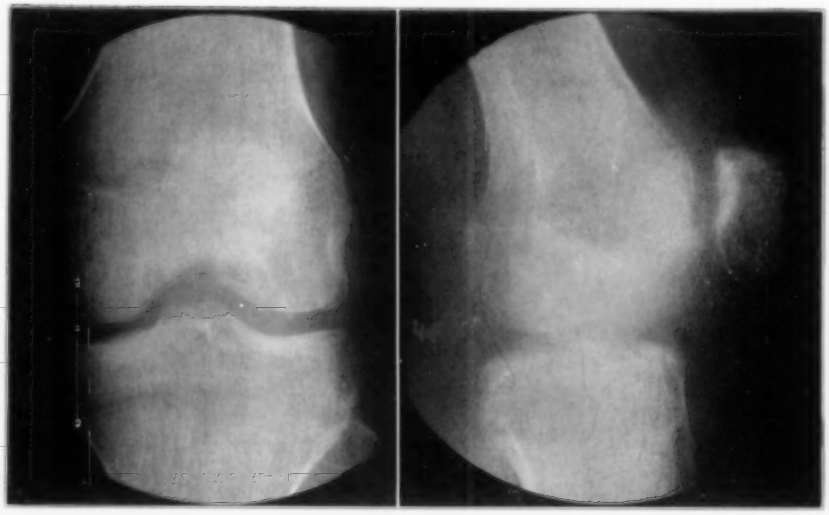

FIG. 1-B

FIG. 1-C

When a portion of the articular surface of a joint is broken free and is completely detached from its circulation, that portion which is composed of bone dies, but that portion composed of articular cartilage lives. This has been noted over and over again in the heads of femora that have been removed in non-union. A year later the replaced head of the femur will be found covered with living hyaline cartilage, whereas the subjacent bone will be avascular and necrotic. The explanation is that the hyaline cartilage is able to extract what it needs for the survival of its cells from the joint fluids, whereas the bone cells in their lacunae and in the Haversian canals cannot survive without blood circulation. The result is that in all fractures and in all injuries to bone in which blocking of the circulation, either gross or microscopic, occurs, avascular necrosis of the bone is inevitable.

The subsequent history of such necrotic bone has been studied exhaustively and it is known that if circulation is re-established the dead bone will be invaded by myriads of active osteoblasts which will absorb and ultimately replace it with living bone. This is what happened to our loose piece of femoral condyle. It promptly united to its bed and new circulation developed; it was invaded by osteoblasts, and was soon replaced by new living bone. The cartilage on its surface had survived and had remained essentially undisturbed by the changes occurring beneath it.

In order to satisfy ourselves that, when segments of articular surfaces are cut free

FIG. 2-A

FIG. 2-B

from their circulation, the bone dies and the articular cartilage lives, a series of experiments on dogs was carried out by Dr. Ian Macnab in the University Laboratories in Toronto, in which small segments of the head of the femur were removed and replaced. The specimens when recovered confirmed completely the statement that the transplanted bone dies and the articular cartilage lives unchanged.

The most illuminating study of this subject is that by E. B. Tovee [1] who made sub-

FIG. 2-C

FIG. 3

capital fractures of the neck of the femur in dogs, and then, after making sure that all circulation to the head had been severed, replaced the heads in the joints and fastened the fractured surfaces accurately together with a single screw. As in the case of our avulsed femoral condyle these fractures of the neck united rapidly and the dead bone was quickly invaded by osteoblasts and was ultimately completely replaced. The articular cartilage remained unchanged.

This study left unsolved the observation that, in dogs, union of the subcapital fracture, with rapid replacement of the necrotic head, occurs in 100 per cent of cases, whereas in human patients the percentage of such perfect results, even when accurate reduction and fixation have been secured, is not nearly so high. The explanation seems to be that in dogs the head of the femur is small and the distance the new circulation and the invasion of osteoblasts have to advance is very short compared with what is necessary in a human hip. The study of sections made through the head of a human femur, in which union of the fracture has occurred, but collapse of a V-shaped segment has ensued, shows that revascularization and replacement had gone as far as the border of the V-shaped segment and had there simply absorbed sufficient of the cancellous structure to allow collapse or had actually caused the separation of this V-shaped portion of the head as a sequestrum. It would seem that there is a limit to the distance that the process of revascularization and replacement can be expected to advance with certainty. If, however, as in the case of our avulsion-fracture of the condyle of the femur, the distance the invading process has to advance is not too great, let us say not more than a third of an inch, one may anticipate perfect healing of the fracture and a normal articular surface.

That the principle of the transplantation of articular surfaces is sound is demonstrated in the operation we have used for many years for the correction of hallux valgus. In this operation the exostosis is chiselled off and then a segment of the head of the metatarsal, just behind the articular cartilage, about a quarter inch thick, is removed, and the little plate of articular cartilage with its underlying thin layer of bone is dropped back on the end of the shaft. When the toe is straightened, this thin disc of cartilage and bone is pressed firmly against the end of the shaft and soon becomes attached to it. The ultimate result is the permanent correction of the deformity and a free-moving joint. Roentgeno-

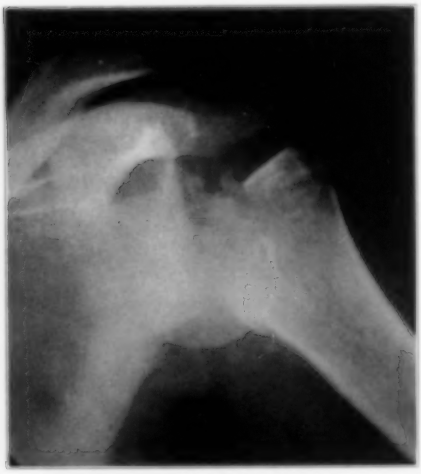

FIG. 4-A

FIG. 4-B

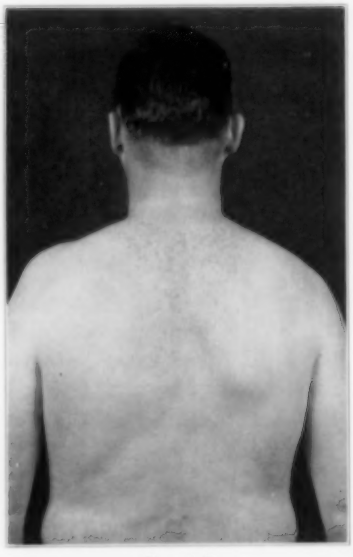

FIG. 4-C

FIG. 4-D

FIG. 4-E

grams made ten years later show a normal joint space (Figs. 2-A, 2-B, 2-C).

With this clear evidence that an articular surface can be transplanted successfully, it seems a great pity that we are not making greater use of our knowledge to restore motion in ankylosed joints. Arthroplasty, with real viable articular cartilage, would be wonderful. Unfortunately, however, one must use autogenous material for transplants. Experience has taught us that homogenous and heterogenous material cannot live, and the grafting procedure is, therefore, bound to fail. Yet the certainty that free motion can be retained after the avulsion of articular surfaces or after transplantations, as in hallux valgus

operations, or after such operations as were done on Tovee's dogs, makes one wonder if there might not be other places where the repairing of joint surfaces would prove useful.

I have had an opportunity to try it out on only three occasions, once in a hip, once in an elbow (Fig. 3), and once in a shoulder. In the case of the hip there had been a subcapital fracture of the neck of the femur with non-union. At operation a Whitman reconstruction was done. In addition, a thin slice of the head of the femur was placed on the top of the stump of the neck. Whether it improved the final result is problematical. In all probability the method described by John Royal Moore in which he reams out the dead head until only a thin layer of bone is left on the deep side of the cartilage, and fits the reamed-out head accurately on the shaft of the neck would have proved better. In the elbow, the capitellum had been broken off and grossly displaced some months previously. It was excised, was reduced in thickness, and was placed in a bed prepared for it in the lower end of the humerus. A decided improvement in the range of movement resulted. In the shoulder, an old fracture-dislocation, the head was excised and a slice of it was planted on the upper end of the shaft so as to articulate with the glenoid. The result was the best I had ever seen after old fracture-dislocation of the shoulder (Figs. 4-A through 4-E).

Now, while these three cases cannot be presented as brilliant examples of arthroplasty by the transplantation of autogenous articular surfaces, yet they were sufficiently successful to suggest that there may be other places where the principle could be employed. For instance one might deliberately remove the articular surfaces of a talonavicular joint and transplant them to a hip joint. The loss of motion in the mid-tarsal joint would be of small importance if one could in exchange obtain painless motion in the hip.

It has been our failure to solve this baffling problem that accounts for the present enthusiasm for replacement therapy. However, while there is no doubt that arthroplasties based on the introduction of cups and other prostheses occupy a useful place in surgery, yet, they are, after all, crude attempts at the repair of injured joints. I am convinced that if we, as surgeons, are to maintain our position in competition with the modern physician, the biochemist, and the physiologist we must seek our inspiration from the study of the great principles of anatomy and physiology which govern all living processes rather than from the comparatively simple mechanics of the machine shop.

1. Tovee, E. B.: Fractures of the Neck of the Femur. (Unpublished paper read at the Annual Meeting of The American Orthopaedic Association, June 20, 1953.)

DISCUSSION

Dr. John R. Moore, Philadelphia, Pennsylvania: It is a privilege to have read and listened to the presentation of this extremely important fundamental contribution to orthopaedic surgery. The author has submitted material and has proved that cartilage in the presence of joint fluid remains viable. The cartilaginous-cup arthroplasty described in 1948[a] was based on this assumption and subsequent experimental work at the Shriners' Hospital for Crippled Children in Philadelphia and at Temple University School of Medicine (not as yet published) has supported this impression. The first patient subjected to a cartilaginous-cup arthroplasty, performed in 1939, died in 1948. The hip was obtained after death and normal hyaline cartilage was found covering the head and in the acetabulum. Dr. Gallie's paper is timely and extremely valuable.

a. Moore, J. R.: Cartilaginous-Cup Arthroplasty in Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **30-A:** 313–330, Apr. 1948.

Prof. R. I. Harris, Toronto, Ontario, Canada: During my long, stimulating, and happy association with Dr. Gallie, there have been many occasions on which we have had an opportunity to discuss the principle which he has enunciated this morning. I can affirm that the examples that he has shown are good examples of the successful transplantation of articular surfaces. Dr. Gallie has pointed out that the opportunities which one has to apply these principles are limited because of the lack of viable cartilage to cover the end of a bone and because the cartilage must be from the patient himself; it must be autogenous transplantation rather than homogenous transplantation. Perhaps I can illustrate our experience and emphasize what Dr. Gallie has said by indicating one further condition in which the principle is of value—namely, in certain cases of osteochondritis dissecans.

FIG. 1

FIG. 2

FIG. 3

Dr. Green and his associates of the Boston Children's Hospital have recently pointed out that osteochondritis dissecans need not be treated surgically, with the removal of the involved portion of the articular surface[a]. I wish to indicate that when the fragment is already completely separated or nearly so, the principle which Dr. Gallie has enunciated this morning can be applied successfully.

Figure 1 is a roentgenogram of the knee of a sixteen-year-old boy who, while pushing a wheel barrow up a ramp, slipped and twisted his knee. He did not fall. The roentgenogram shows the separation of two large fragments from the lateral condyle of his femur posteriorly. The symptoms were not severe, so he was observed for a period of three years. During that time his symptoms persisted; finally, it was decided that he should be operated upon. At operation the two fragments were completely separated from the femur, although the articular cartilage still bridged a small amount of the periphery. Each fragment was completely removed from its bed, the bed was freshened, and the fragments were replaced. In Figure 2, the fragments are shown held in place. Their density is greater than that of the surrounding bone. Figure 3 shows restoration of the external condyle of the femur. There has been complete healing of the fragments in the bed in which they lie. The patient is now completely free from symptoms.

a. GREEN, W. T., and BANKS, H. H.: Osteochondritis Dissecans in Children. J. Bone and Joint Surg., **35-A:** 26–47, Jan. 1953.

Legg-Perthes Disease

Observations on Pathological Changes in Two Cases

BY IGNACIO V. PONSETI, M.D., IOWA CITY, IOWA

From the Department of Orthopaedic Surgery, State University of Iowa, Iowa City

There now seems to be general agreement that in Legg-Perthes disease the femoral head becomes necrotic because of impairment of its blood supply [1, 2, 3, 4, 10, 13, 15]. The cause of this impairment of blood supply is unknown.

We recently described a lesion in epiphyseal plates produced in young rats fed diets containing aminonitriles [11, 17]. Epiphyseal slipping was commonly observed in these experimental animals. Occasionally, without any evidence of gross epiphyseal slipping, the femoral head became necrotic, simulating Legg-Perthes disease.

Biopsy specimens were obtained from two children with clinical and roentgenographic findings typical of the early stages of Legg-Perthes disease. The biopsy specimens were obtained by means of a Phemister punch, one centimeter in diameter, introduced through the outer aspect of the upper femoral shaft into the center of the femoral neck and head. The biopsy specimens broke at the epiphyseal plate. Both pieces of bone were wrapped in gauze and were kept in their anatomical position during the decalcification and embedding in celloidin. The decalcification was done in a 6 per cent aqueous solution of sulphosalicylic acid. Sections were obtained from the blocks and were stained with hematoxylin and eosin.

Fig. 1

Case 1. Roentgenogram of the right hip. There is increased density of the femoral head and decreased density of the metaphysis.

Case 1 (V. M.): A seven-year-old white girl was first seen at the State University of Iowa Hospital in July 1955. Five months prior to admission, she had jumped off the slide at school. She had immediately noted pain in the right hip and had started to limp. The limp persisted, but the pain disappeared after three months. Her past medical history was non-contributory.

On examination the child appeared to be healthy and somewhat obese. She was forty-seven inches high and weighed seventy-five pounds. The general physical examination was negative except for a fair degree of limitation of motion in all directions in the right hip. The right lower extremity was one-half inch shorter than the left. She walked with an antalgic limp on the right. Tests for syphilis were negative. Laboratory examinations showed values within normal limits for the following: sedimentation rate, plasma protein-bound iodine, hemoglobin, erythrocyte count, and leukocyte count.

The roentgenograms showed increased density of the right femoral head, except for a small area in its outer margin which appeared to be less dense. The epiphyseal plate was irregularly outlined. There was decreased density of the metaphysis. The distance between the femoral head and the inner wall of the acetabulum was slightly wider on the right hip than on the left. The femoral neck was also slightly wider on the right side (Fig. 1).

Histological Examination

The bone and bone marrow in the portion of the femoral head obtained at the biopsy

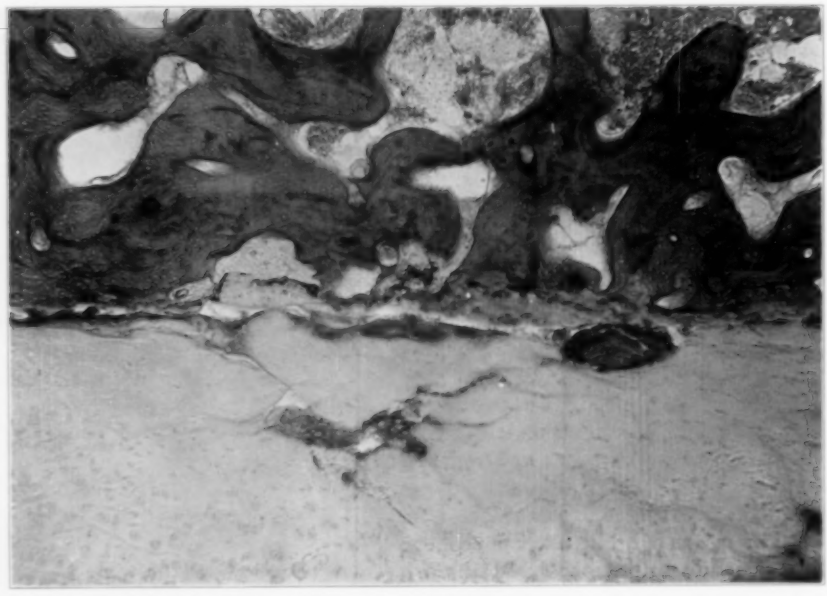

FIG. 2

Case 1. Photomicrograph (× 55) of the junction of the femoral head and epiphyseal plate. The bone is necrotic, and there are some cartilage cells in between the bone trabeculae. Clefts containing débris and some extravasated blood are seen in the epiphyseal cartilage.

FIG. 3

Case 1. Photomicrograph (× 85) showing the line of endochondral ossification. A tongue of fibrillated cartilage is seen penetrating into the metaphysis.

were necrotic. There were a few clusters of live cartilage cells between the bone trabeculae close to the epiphyseal plate. Endochondral ossification at the site of the femoral head had ceased completely. However, the line of demarcation between the femoral head and the epiphyseal plate was uneven, and a few blood vessels and some extravasated blood were present at that site. A few small tongues of cartilage cells penetrated for a short distance between the bone trabeculae of the femoral head. The matrix in some of these tongues appeared to have degenerated; it was granular, stained with eosin, and contained small vessels which brought the blood supply to an adjacent marrow space (Figs. 2 and 4).

The joint cartilage appeared to be normal except for the deeper layers adjacent to the necrotic epiphyseal bone where some clustered cartilage cells appeared; a few of these were necrotic. In several of these areas the cartilage matrix was fibrillated.

The epiphyseal plate was distorted by the break which had occurred just proximal to

FIG. 4

Case 1. Photomicrograph (× 100) showing a tongue of degenerated epiphyseal-plate cartilage penetrating into the femoral head. Blood is seen in the adjacent marrow space. The bone is necrotic. The cartilage cells are clustered, and the matrix is degenerated.

the proliferating cells when the biopsy specimen was being obtained. However, enough remained undamaged to show its main features. The cartilage cells were clustered, and the cartilage matrix was unevenly stained and fibrillated. Large clefts were observed containing eosin-stained, amorphous material and some extravasated blood (Fig. 2). Endochondral ossification was normal in some areas; in other areas, the rows of proliferating cells were separated by fibrillated, eosin-stained cartilage matrix which did not calcify. Here the cartilage cells did not degenerate in the usual manner but proliferated. Endochondral ossification did not take place; this left tongues of cartilage in the metaphysis as bone growth proceeded in the adjoining areas (Fig. 3). Tongues of completely degenerated cartilage extended deep into the femoral neck and often terminated in large islands of cartilage surrounded by areas of endochondral ossification (Figs. 5 and 6). Isolated islands of cartilage were also present in the femoral neck. No necrotic bone was seen in the metaphysis or in the femoral neck, and there was no osteoid tissue. The bone trabeculae in the

FIG. 5

Case 1. Photomicrograph (× 150) showing the line of endochondral ossification interrupted by a tongue of degenerated cartilage. The ground substance appears granular and does not calcify. A large cystic space is seen in the marrow.

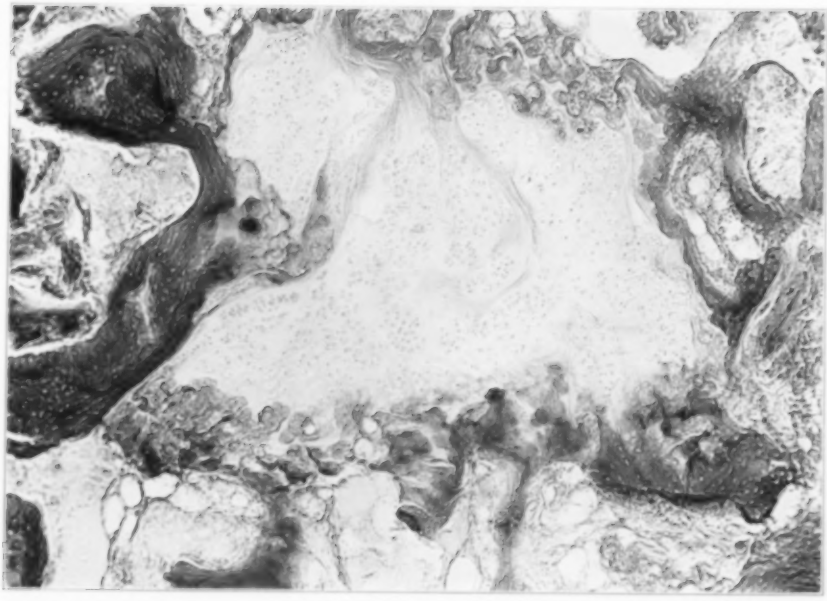

FIG. 6

Case 1. Photomicrograph (× 80) showing a large area of cartilage in between the bone trabeculae of the femoral neck. This area of cartilage was at the end of the tongue shown in Fig. 5.

metaphysis appeared irregularly arranged and many clusters of cartilage cells were seen between them. An occasional large cystic space was seen. The bone marrow was normal. There were no inflammatory cells in any of the slides studied.

CASE 2 (D. C.): An eleven-year-old white male was first seen at the State University of Iowa Hospital in June 1955. Seven months prior to admission, he had complained of pain in the left hip and had begun to limp. He had no pain at night. The symptoms persisted to the time of admission to the Hospital. His past medical history was non-contributory. The general physical examination was negative except for a slight degree of limitation of motion in all directions in the left hip. The left lower extremity was one-half inch shorter than the right. The left thigh measured one inch less in circumference than the right. He walked with an antalgic limp on the left. The following laboratory examinations showed values within normal limits: hemoglobin, erythrocyte count, leukocyte count, serum calcium, phosphorus, and alkaline phosphatase.

The roentgenograms showed increased density and some flattening of the left femoral head. The epiphyseal plate was irregularly outlined. There was a wide zone of decreased density in the metaphysis, with an irregular sclerotic narrow band below it. The distance between the femoral head and the inner wall of the acetabulum was wider on the left hip than on the right. The femoral neck was also slightly wider on the left side (Fig. 7).

FIG. 7

Fig. 7: Case 2. Roentgenogram of the left hip. There is increased density and flattening of the femoral head and decreased density in the metaphysis.

Histological Examination

The bone and bone marrow of the portion

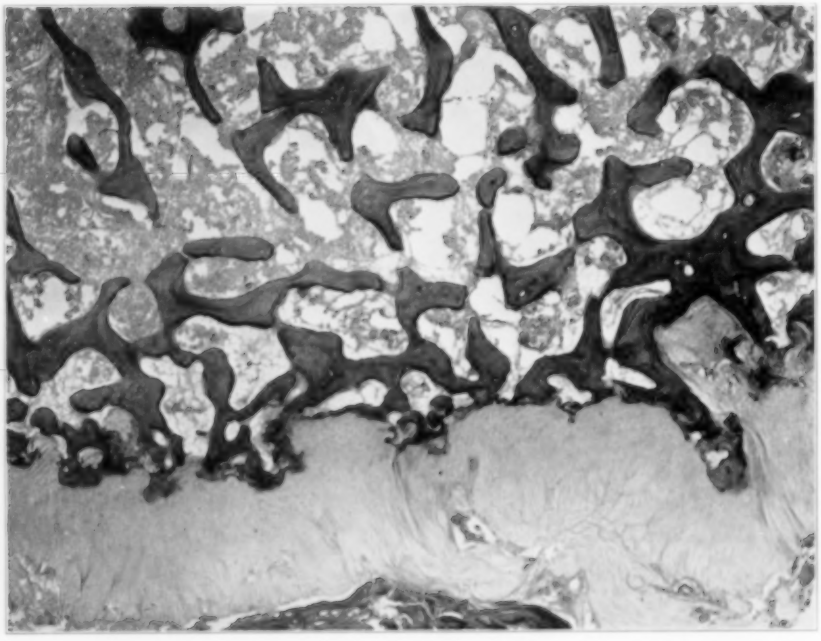

FIG. 8

Case 2. Photomicrograph (× 19) showing a portion of the femoral head and of the distorted epiphyseal plate. The bone and bone marrow are necrotic.

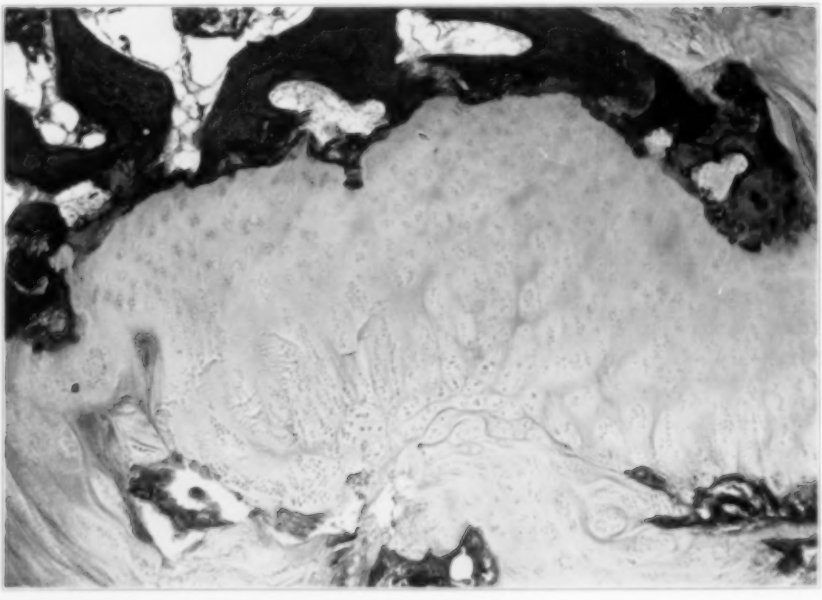

FIG. 9

Case 2. Photomicrograph (× 55) of the epiphyseal plate. The cartilage is unevenly stained, fibrillated and the cells are clustered. Rents filled with débris and extravasated blood are seen. Most of the bone is necrotic but there are a few areas where creeping substitution is taking place.

of the femoral head obtained at biopsy were necrotic except for the area adjacent to the epiphyseal plate. Here small areas of creeping substitution were seen, and there were live cells in a few marrow spaces. A few islands of clustered cartilage cells were seen between the bone trabeculae not far from the epiphyseal plate. The line of demarcation between the femoral head and the epiphyseal plate was very uneven. Some necrotic bone trabeculae and irregularly calcified cartilage protruded into the epiphyseal plate. In some places wide tongues of degenerated cartilage, containing a few small blood vessels, appeared to penetrate for a short distance into the femoral head (Figs. 8 and 9).

The joint cartilage appeared to be normal except for a few areas of fibrillated cartilage adjacent to the subchondral line (Fig. 10).

The epiphyseal plate was distorted, as it was in Case 1, by the break which had

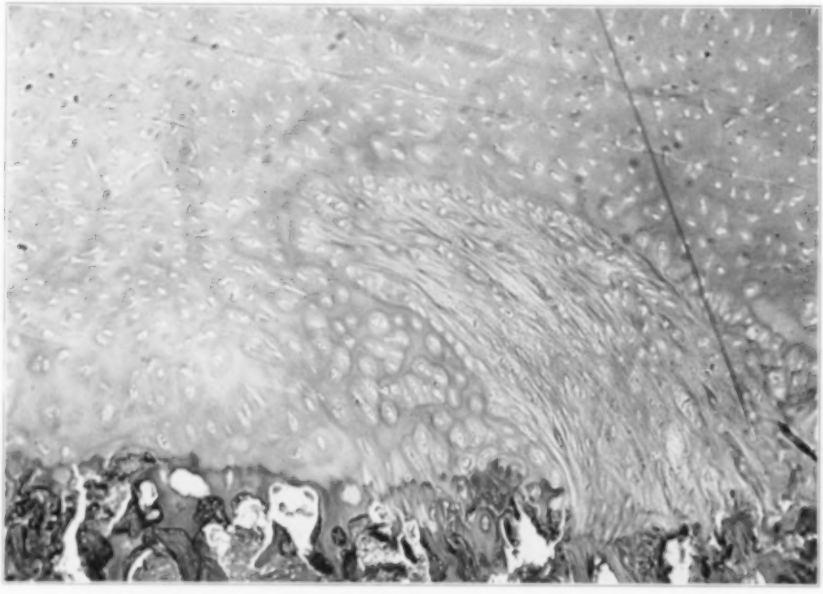

FIG. 10

Case 2. Photomicrograph (× 60) of the joint cartilage. There is an area of fibrillated cartilage. Some of the cartilage cells and the subchondral bone are necrotic.

occurred through its center when the specimen was being obtained at biopsy. Large areas of the plate, however, remained undamaged. As in Case 1, the cartilage cells appeared clustered and the cartilage matrix was unevenly stained, fibrillated, and crossed by extensive clefts filled with extravasated blood and amorphous material (Fig. 9). Endochondral ossification was even more deranged than it was in Case 1. Large tongues of fibrillated cartilage containing clustered cells, débris, and extravasated blood appeared to penetrate deep into the femoral neck (Fig. 11). Irregularly calcified cartilage and some areas of endochondral ossification were observed at the margins of these tongues (Fig. 12). Islands of cartilage completely surrounded by bone remained deep in the femoral neck. The bone trabeculae in the metaphysis were irregularly arranged, but there was no necrotic bone or osteoid tissue. The bone marrow was not unusual except for the cartilage intrusions. No inflammatory cells were seen.

DISCUSSION

The main features observed in the biopsy specimens of the two cases presented were necrosis of the femoral head and disruption of the epiphyseal plate with the resultant

irregular endochondral ossification. The epiphyseal-plate lesion was obviously a long-standing condition as large tongues of disarranged cartilage extended deep into the femoral neck. The necrosis of the bone and bone marrow of the femoral head may be assumed to be fairly recent in our two cases, and especially in Case 1, as little or no evidence was encountered of replacement of the dead tissues by living cells. It appears that in Legg-Perthes disease the faulty epiphyseal-plate cartilage is the primary lesion. The necrosis of the epiphysis ensues when its blood supply becomes interrupted. We surmise that this interruption occurs when the retinacular vessels cross the thick layer of cartilage at the edge of a badly disrupted epiphyseal plate (Fig. 13). The rent formation and some jarring of the weakened plate due to trauma may be enough to impair the continuity of the vessels before they reach the ossifying femoral head. The vessels of the ligamentum teres cannot afford any relief to the ischaemic femoral head because they do not enter the bone until the ossification has extended to the fovea, approximately between the twelfth and fourteenth year of life [18].

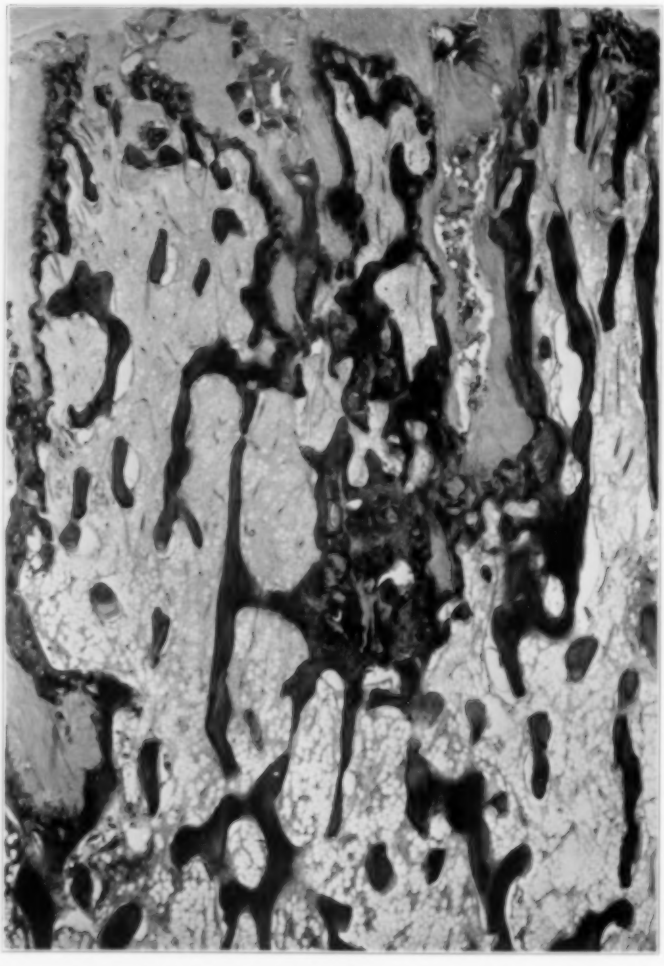

FIG. 11

Case 2. Photomicrograph (× 19) of the metaphysis. Extensive tongues of cartilage extend from the epiphyseal plate into the femoral neck.

Bone necrosis in different stages of repair has been described in most previous reports of biopsy specimens from the femoral head in Legg-Perthes disease. Some authors have also reported anomalies in the upper femoral epiphyseal plate [2, 4, 9, 7, 15, 19]. The biopsy specimens offered us an opportunity to study the changes in two fairly early cases of Legg-Perthes disease, when the lesions are little masked by the reparative processes. The epiphyseal-plate lesion seen in our two cases can now be better understood because histologically it appears similar to the epiphyseal-plate lesion produced in rats by the administration of aminonitriles in their diets [11]. It appears that first the ground substance of the cartilage becomes defective. There is fibrillation and rent formation. The cartilage cells react by proliferation and tend to cluster. The distortion of endochondral ossification is not caused by a defect of calcification as in rickets but is possibly due to the disturbed maturation of the cartilage. No ossification occurs in the fibrillated areas containing large amounts of granular matrix. As endochondral ossification proceeds in less deranged areas, tongues

FIG. 12

Case 2. Photomicrograph (× 65) of the metaphysis showing a large tongue of cartilage, with areas of calcification and ossification.

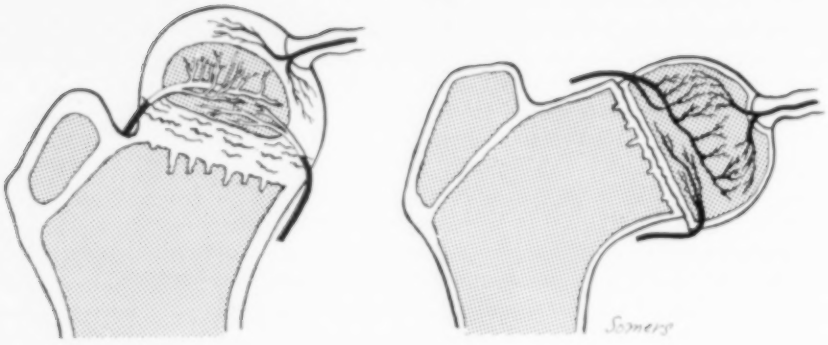

FIG. 13

Diagram to illustrate the production of Legg-Perthes disease and of epiphyseal slipping.

of uncalcified cartilage remain in the metaphysis and may be found later as islands of cartilage in the femoral neck. The bone trabeculae are well ossified, and no osteoid tissue is present. A similar abnormality of the endochondral ossification at the epiphyseal side is apparently responsible for the presence of tongues and isolated islands of cartilage in the femoral head.

It is now possible to understand the changes which are observed in the roentgenograms during the early stages of Legg-Perthes disease. There is first decreased density in the metaphysis, as pointed out by Gill. The epiphyseal plate is irregular. The distorted endochondral ossification and the large tongues and islands of cartilage seen in the metaphysis in our biopsy specimens explain these changes. The increased density of the femoral head is the result of the ischaemic bone necrosis. Ray and his associates have shown that the increased density in aseptic necrosis of bone as seen roentgenographically "is probably the result of combined failure of mobilization of inorganic salts and continued uptake by the necrotic bone from the tissue fluids, in addition to the decrease in density of the surrounding viable bone".

The etiology of Legg-Perthes disease remains unknown. Children with this disease could have some metabolic disturbance or perhaps eat foods containing excessive amounts of aminonitriles. In any case, it is likely that the disease is not localized to the upper portion of the femur [14]. Gall and Bennet in the postmortem study of their case with bilateral Legg-Perthes disease found irregularities of the upper femoral epiphyseal plate and marked derangement of the cartilage-cell columns. They also observed similar irregularities in the epiphyseal plate of the greater trochanter, of the acetabulum, and at the costochondral junctions. Apparently other epiphyseal plates were not examined. Skeletal surveys of patients with Legg-Perthes disease done by us have shown some irregularities in other epiphyseal plates. In several cases the disease was bilateral. Disturbances of the acetabular ossification and Van Neck's disease were observed. Köhler's disease was found in two cases. It is apparent that in children with Legg-Perthes disease, other ossification centers are deranged in addition to those of the femoral heads. The peculiar blood supply of the femoral head probably accounts for the more serious consequences of the lesions in the upper femoral epiphyseal plate than in any other epiphysis.

The joint cartilage appeared to be little altered in our two patients except for a few small fibrillated areas adjacent to the subchondral plate. It is important to note that the degeneration of the epiphyseal-plate cartilage in children with Legg-Perthes disease simulates very closely the cartilage changes in the early stages of osteo-arthritis in older patients. This was suggested years ago by Lang. In this regard, our experimental work with rats fed aminonitriles is of interest [11]. In adult rats which had been on the experimental diets

for a few months joint lesions developed similar to those of osteo-arthritis in human patients. In patients with Legg-Perthes disease the damage to joint cartilage is very slight when compared with that from the lesions in the epiphyseal plate, possibly owing to the slow rate of turnover of the joint cartilage. In a child, a metabolic aberration, which induces a chemical change in the cartilage matrix, will readily affect the epiphyseal plate where the cartilage has a very fast rate of growth.

The epiphyseal-plate lesions in our two patients are similar to the lesions previously described in patients with slipping of the upper femoral epiphysis. The reasons Legg-Perthes disease occurs during the first decade of life and epiphysiolysis occurs in the second decade may have to be found in the anatomical changes which take place in the femoral head and neck at the beginning of adolescence. The following explanation seems plausible (Fig. 13):

1. Slipping of the femoral head does not occur in children because the upper femoral epiphysis is nearly horizontal and the periosteum is thick and offers a strong support to the plate and femoral head. "In adolescents the periosteum of the femoral neck begins to atrophy and approach the adult type thus tending to produce a point of weakness in the epiphyseal line" [6]. The epiphyseal plate becomes oblique in the adolescent with the result that an excessive shear is applied to the epiphyseal plate when the patient assumes an antalgic gait owing to the lesion. This shear facilitates slipping [5].

2. In children, the retinacular vessels must penetrate through an extensive area of cartilage to reach the ossification center of the femoral head. Thus, cleft formations in the cartilage and slight trauma to the weakened plate may disrupt the continuity of these vessels, causing necrosis of the head. The artery of the ligamentum teres does not reach the ossified portion of the head until the ossification extends to the fovea, usually between the twelfth and fourteenth years of life [18]. In adolescents, the femoral head is completely ossified and the retinacular vessels reach it after piercing the mature joint cartilage. As the mid-cervical parts of the retinacular vessels are quite mobile [16], these vessels often will not become disrupted even in severe epiphysiolysis and the femoral head will remain viable.

SUMMARY

Biopsy specimens of the femoral head and neck of two patients with Legg-Perthes disease have shown a necrotic femoral head and a disrupted epiphyseal plate. The epiphyseal-plate cartilage was fibrillated and cracked, the cells were clustered, and the line of endochondral ossification was irregular. The epiphyseal-plate lesion appeared to be a long-standing condition, as large tongues of deranged cartilage and cartilage islands were seen very deep in the metaphysis and some in the femoral head. There was some fibrillation in areas of the joint cartilage adjacent to the subchondral plate. There were no signs of infection, rickets, or scurvy. The epiphyseal-plate lesion appears to be caused by a loss of cohesion of the cartilage matrix presumably owing to an alteration of the chemical composition of the ground substance. It is surmised that the loss of blood supply to the femoral head results from the interruption of the retinacular vessels when they cross the cartilage at the edge of the disrupted epiphyseal plate. Jarring of the weakened plate may traumatize and occlude these vessels. The epiphyseal-plate lesion in these two patients is similar to the lesion observed in patients with slipping of the upper femoral epiphysis. It is also similar to the epiphyseal-plate lesion observed in rats fed diets containing aminonitriles.

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Transposition of the Tibialis Anterior in the Treatment of Paralytic Talipes Calcaneus

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It is recognized that paralytic talipes calcaneus is one of the most disabling deformities that may develop in the paralytic foot. If allowed to progress until there is equinus deformity of the fore part of the foot, contracture of the plantar fascia, cavus, and clawing of the toes, the deformity also becomes one of the most difficult for the orthopaedic surgeon to correct satisfactorily.

Irwin, in an excellent presentation, described in detail the components that are involved in the production of calcaneocavus deformity and his method for obtaining correction. He stressed the importance of early tendon transposition, preferably the peroneals or tibialis posterior, as a means of halting or retarding the development of the deformity, improving the gait, creating a counter-thrust against which the remaining intact muscles can function, of stimulating more normal growth, and of obtaining a foot of more normal size and appearance later when stabilization is performed. Peabody called attention to this also. In his experience transposition of the tibialis anterior to the calcaneus was the most effective means of restoring a heel-and-toe gait and the ability to stand on tiptoe.

It is the purpose of this presentation to emphasize the value of early transference of the tibialis anterior into the heel in selected patients as an efficient method of preventing the development of a serious paralytic talipes calcaneus. This procedure has been used by some orthopaedic surgeons in the past, but it has not received the emphasis that it

FIG. 1

FIG. 2

Fig. 1: A short linear incision is made over the medial aspect at the base of the first metatarsal, the tibialis anterior tendon is isolated and is divided at its insertion.

Fig. 2: The tibialis anterior tendon is withdrawn through an incision approximately three inches proximal to the ankle joint. A wide opening is made in the interosseous membrane and the tendon is passed posteriorly between the tibia and the fibula. The tendo achillis is split at its insertion to the calcaneus and the tibialis anterior tendon is drawn through this opening.

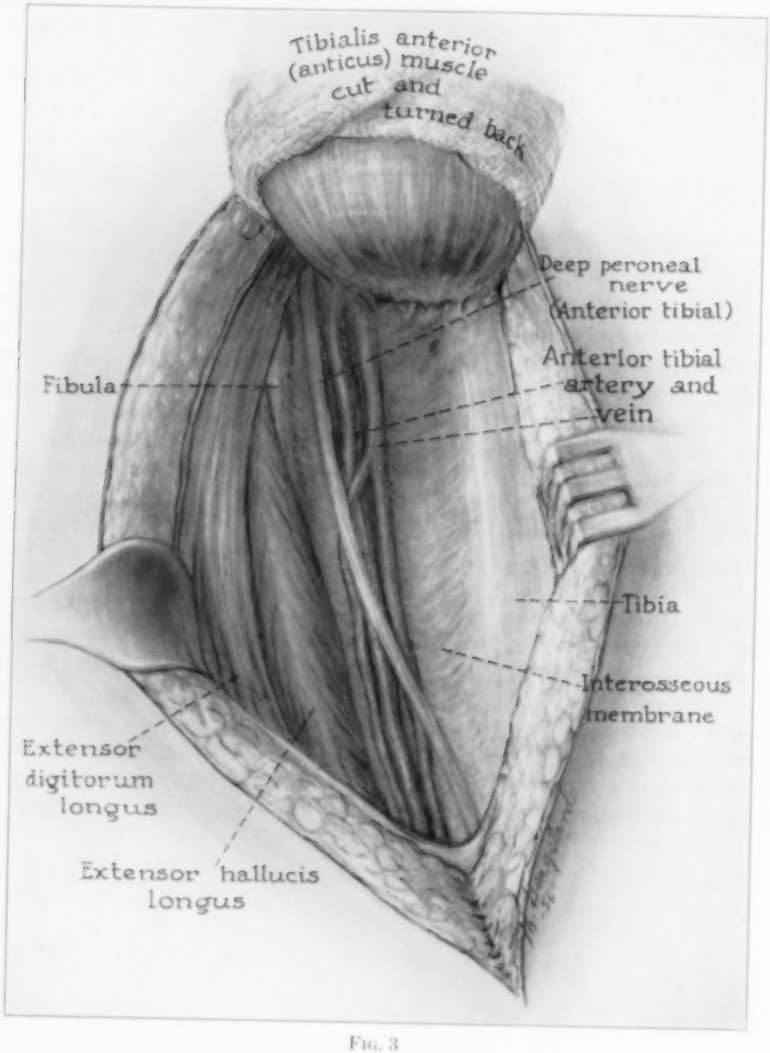

FIG. 3

In preparing the opening in the interosseous membrane, the anterior tibial artery and vein and the deep peroneal nerve should be visualized and protected.

deserves. Fear of resulting drop-foot or interference with the gliding action of the transferred tendon by a constricting interosseous membrane has probably deterred many surgeons from using the tibialis anterior.

The authors have used many other techniques in an attempt to control this deformity, some with considerable success, others with disappointment. Transposition of the peroneals and tibialis posterior into the heel either as isolated or combined transfers; tenodesis of the tendo achillis, either alone or combined with tendon transfer; and even astragalectomies have been done. In our experience, however, isolated transfer of the tibialis anterior into the heel has consistently given the most gratifying results.

It is obvious that in considering the methods available to the orthopaedist in the treatment of a given patient with paralytic talipes calcaneus, the method selected will necessarily be dependent upon the residual muscle power available. For a short period

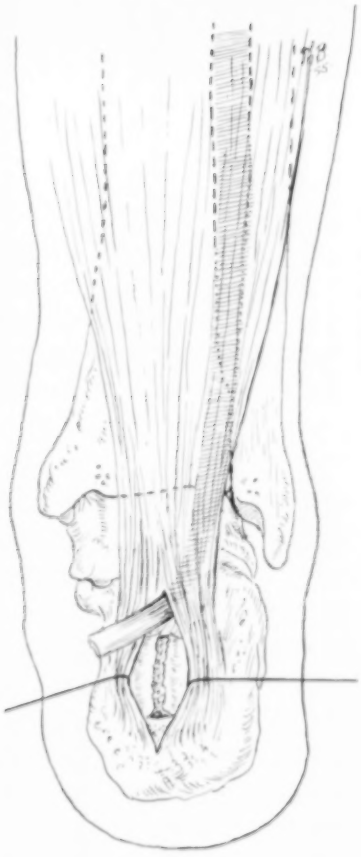

FIG. 4

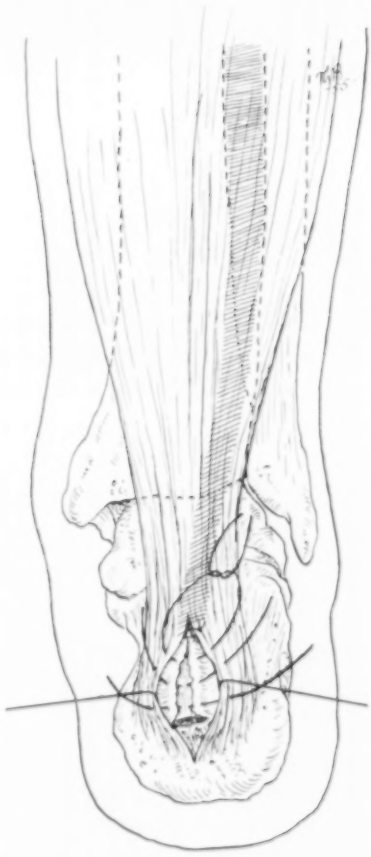

FIG. 5

Fig. 4: The split tendo achillis is retracted and a thin H-shaped osteoperiosteal flap is raised at the posterior surface of the calcaneus large enough to accommodate the tendon of the tibialis anterior.

Fig. 5: The tibialis anterior tendon is buried under the osteoperiosteal flap. Reinforcing sutures are taken to the tendo achillis proximally and the tendo achillis is repaired.

of time the deformity may perhaps be held in check by a brace, but as a rule the deformity will progress in spite of the most careful attention to bracing. We are convinced, therefore, that early surgical intervention is indicated in order to eliminate the deforming force and to utilize available motor power for push-off of the foot. We have performed tendon transposition as early as eighteen months after the onset of acute poliomyelitis and believe that it should be done as soon as it is obvious that there will be no further recovery of power in the gastrocnemius or the soleus. Our objective is to restore the power of plantar flexion before a serious talipes calcaneus develops. If the tibialis anterior is paralyzed, either the peroneals or the tibialis posterior or both are transferred into the heel, depending upon their strength and the strength of the long extensors of the toes. If, however, there is an isolated paralysis of the gastrocnemius and soleus with strong well-balanced lateral stabilizers, strong long extensors of the toes, and a strong tibialis anterior, we elect to transfer the tibialis anterior posteriorly. Next to the gastrocnemius and the soleus, the tibialis anterior is the strongest muscle in the foot and will most nearly replace lost plantar flexion. Normal long extensors of the toes will be strong enough to prevent

TABLE I

TABULATION OF PATIENTS IN WHOM THE TIBIALIS ANTERIOR WAS TRANSPLANTED INTO THE HEEL FOR PARALYTIC CALCANEUS

Patient Age at Onset of Poliomyelitis	Age on Date of Operation	Muscle Evaluation Before Operation	Duration of Follow-up	End Result
1. L.R. 1 yr., 8 mos.	4 yrs. (2/18/53)	Gastrocnemius, soleus, O Toe extensors, G Lateral stabilizers, G (balanced) Tibialis anterior, G	2 yrs., 5 mos. (8/5/55)	Excellent Can walk on toes, maintaining excellent alignment of foot and does not excessively dorsiflex great toe.
2. B.L. 4 yrs.	9 yrs. (5/17/50)	Three years previously had had triple arthrodesis and transplant of peroneals into heel cord. Severe paralytic calcaneus persisted. Tibialis anterior, G Toe extensors, G	4 yrs., 9 mos. (2/18/55)	Fair Much improved but still cannot walk on toes. Foot stable.
3. G.S. Infant	8 yrs., 10 mos. (4/16/52)	Gastrocnemius, soleus, T, P Toe extensors, N Lateral stabilizers, N Tibialis anterior, N	3 yrs., 3 mos. (7/15/55)	Good Complete correction of calcaneus but foot is going into slight valgus. Can walk on toes. Transposition of extensor hallucis longus performed June 30, 1954.
4. J.G. 1 yr., 7 mos.	3 yrs., 6 mos. (9/20/50)	Gastrocnemius, soleus, O Toe extensors, G Tibialis anterior, G Tibialis posterior, G Peroneals, P, F	4 yrs., 10 mos. (7/27/55)	Good Calcaneus controlled. Can walk on toes. Slight varus due to weak peroneals, and cock-up toe developed. Triple arthrodesis and transposition of extensor hallucis longus performed July 6, 1955.
5. M.K. 6 yrs.	8 yrs., 2 mos. (1/21/53)	Gastrocnemius, soleus, O Toe extensors, N Lateral stabilizers, G Tibialis anterior, N Had preliminary plantar fasciotomy because of cavus	2 yrs., 7 mos. (8/5/55)	Excellent Can walk on toes. Mild cock-up of great toe. Good alignment of foot. Can rise on toes with opposite foot raised from the floor.
6. T.W. 1 yr., 6 mos.	4 yrs. (5/7/52)	Gastrocnemius, T, P Toe extensors, N Lateral stabilizers, N	3 yrs., 3 mos. (8/5/55)	Excellent Can walk on toes. With opposite foot raised from floor can rise on toes of affected foot.

		Tibialis anterior, N Mild cavus		Good alignment of foot. Very slight valgus and very slight depression of first metatarsal head.
7. J.W. 3 yrs.	6 yrs. (4/23/52)	Gastrocnemius, soleus, O Toe extensors, N Lateral stabilizers, F (balanced) Tibialis anterior, N	3 yrs., 4 mos. (8/5/55)	Excellent Can walk on toes. Can rise on toes when opposite foot is raised from floor. Good alignment of foot. Very slight valgus and very slight dropping of first metatarsal head.
8. P.Y. 3 yrs.	4 yrs., 6 mos. (4/13/49)	Gastrocnemius, soleus, O Toe extensors, N Lateral stabilizers, G Tibialis anterior, N	6 mos. (10/12/49)	Good Excellent push-off but moderate valgus of heel is developing. Can walk on toes.
9. P.F. 3 yrs., 6 mos.	9 yrs. (7/18/51)	Four years previously peronaeus brevis and tibialis posterior transplanted into heel cord. Severe calcaneus deformity persisted. Eight weeks previously triple arthrodesis. Toe extensors, G Tibialis anterior, G	1 yr., 2 mos. (9/5/52)	Excellent Can walk on toes. Alignment of foot excellent.
10. J.S. 1 yr., 10 mos.	3 yrs., 4 mos. (2/11/53)	Gastrocnemius, soleus, O Toe extensors, G Lateral stabilizers, G Tibialis anterior, G	2 yrs., 6 mos. (8/5/55)	Excellent Can walk on toes. Very slight valgus and very slight cock-up of great toe. Alignment of foot good. Can rise on toes with opposite foot raised from floor.
11. J.W. 4 yrs.	6 yrs. (5/10/55)	Gastrocnemius, soleus, O Toe extensors, G Lateral stabilizers, G Tibialis anterior, G	5 yrs., 2 mos. (7/28/55)	Excellent Can walk on toes. No instability. Maintains good alignment of foot. Transposition of extensor hallucis longus performed July 20, 1955, because of cock-up toes.
12. P.S. 7 yrs.	12 yrs. (8/8/53)	Four years previously had triple arthrodesis and transplantation of peronaeus brevis and tibialis posterior into heel cord. Talipes calcaneus persisted. Toe extensors, G Tibialis anterior, F, G	2 yrs., 10 mos. (8/6/55)	Fair Gait improved. Talipes calcaneus controlled but cannot walk on toes. (Note: In this case tendon was attached to split tendo-achillis and not to bone.)

FIG. 6-A

FIG. 6-B

Figs. 6-A to 6-E: Case T. W. Three and one-half years after transfer of tibialis anterior into the heel. This patient had poliomyelitis at eighteen months of age. Residual muscle power: gastrocnemius and soleus, *trace*; toe extensors, lateral stabilizers, and tibialis anterior, *normal*. Tibialis anterior was transferred into heel at four years of age.

Fig. 6-A: Roentgenograms of the unaffected foot.

Fig. 6-B: Roentgenograms of the foot operated upon.

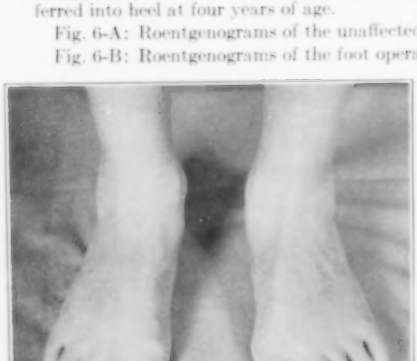

FIG. 6-C

FIG. 6-D

FIG. 6-E

Fig. 6-C: Satisfactory alignment of the foot has been maintained.

Fig. 6-D: Operated foot dorsiflexes above a right angle.

Fig. 6-E: With the opposite foot elevated, the patient can rise on toes of foot operated upon.

drop-foot or the development of an equinus deformity, and normal lateral stabilizers will maintain a surprisingly good alignment of the foot. The authors anticipated, however, that following transfer of the tibialis anterior the valgus pull of the toe extensors combined with the peroneals might overpull the tibialis posterior, and that the foot might go into valgus deformity. Also, it was anticipated that the long extensor to the great toe would substitute for the tibialis anterior and produce a cock-up toe with depression of the first metatarsal head. It was felt that these possible deformities which could be easily corrected by triple arthrodesis and transposition of the extensor hallucis longus into the first metatarsal head at a suitable age would be a small price to pay for the prevention of a disabling talipes calcaneus.

In our early cases of tibialis anterior transposition, we insisted that the patient have normal lateral stabilizers and toe extensors. The patients were told that foot stabilization or transposition of the extensor hallucis longus would probably be necessary at a later age. The results have been so satisfactory, however, that we now use the tibialis anterior as

FIG. 7-A

FIG. 7-B

Figs. 7-A to 7-E: Case J. S. Two and one-half years after transfer of tibialis anterior into the heel. This patient had poliomyelitis at twenty-two months of age. Residual muscle power: gastrocnemius and soleus, *zero*; toe extensors, lateral stabilizers, and tibialis anterior, *normal*. Tibialis anterior was transferred into the heel at three years and four months of age.

Fig. 7-A: Roentgenograms of the foot operated upon.

Fig. 7-B: Roentgenograms of the unaffected foot.

FIG. 7-C

FIG. 7-D

FIG. 7-E

Fig. 7-C: Satisfactory alignment of foot has been maintained.

Fig. 7-D: Foot operated upon can be dorsiflexed to more than a right angle.

Fig. 7-E: With opposite foot elevated, patient can rise on toes of the foot operated upon.

the muscle of choice to transfer for paralytic talipes calcaneus, regardless of the strength of the remaining muscles of the foot, recognizing that any residual imbalance may be dealt with satisfactorily later. We believe that the paralytic talipes calcaneus is by far the most important deformity to be corrected. So far we have not used the tibialis anterior as a transfer in a patient who did not have good toe extensors and have, therefore, not had the complication of equinus deformity. We would not hesitate to do so, however, if the procedure was necessary to prevent a serious talipes calcaneus. The resulting equinus deformity could be controlled later by a posterior bone-block if necessary.

OPERATIVE TECHNIQUE

Skin incisions are made as indicated in Figures 1 and 2. The tibialis anterior is divided at its insertion and withdrawn anteriorly through a short incision approximately three inches proximal to the ankle joint (Fig. 1). A wide opening is made in the interosseous membrane and the tendon is then passed between the tibia and fibula posteriorly.

FIG. 8-A

FIG. 8-B

Figs. 8-A to 8-E: Case J. W. Three years and eight months after transfer of tibialis anterior into the heel. This patient had poliomyelitis at three years of age. Residual muscle power: gastrocnemius and soleus, *zero*; toe extensors, lateral stabilizers, and tibialis anterior, *normal*. Tibialis anterior was transferred into the heel at six years of age.

Fig. 8-A: Roentgenograms of the unaffected foot.

Fig. 8-B: Roentgenograms of the foot operated upon.

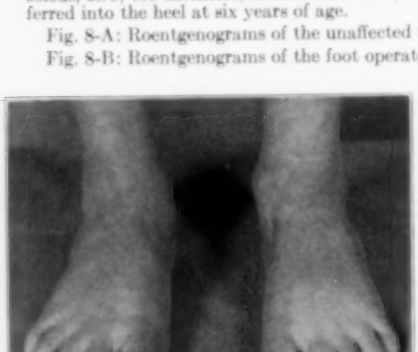

FIG. 8-C

FIG. 8-D

FIG. 8-E

Fig. 8-C: Slight valgus of the foot.

Fig. 8-D: Foot operated upon can be dorsiflexed to more than a right angle.

Fig. 8-E: With the unaffected foot elevated, patient can rise on toes of the foot operated upon.

In our experience, the interosseous membrane at the junction of the middle and lower thirds of the leg presents little resistance to the passing of the tendon between the tibia and fibula (Fig. 3). We have, therefore, made the opening by pushing a blunt instrument through the membrane and then enlarging the opening by spreading a hemostat or Kelly clamp. We have not made an attempt to form a special trap-door opening through the membrane. Care must be used not to injure the anterior tibial artery and the deep branch of the peroneal nerve. The tendo achillis is split at its attachment to the calcaneus (Fig. 3), and the tibialis anterior is buried in a shallow gutter of bone or under an osteoperiosteal flap made at the posterior aspect of the calcaneus at the insertion of the tendo achillis as indicated in Figures 4 and 5. Reinforcing sutures to the tendo achillis are placed for security. This method of attachment is preferred as it gives good bony fixation, and, as the apophysis grows, the tendon is carried with it posteriorly maintaining satisfactory leverage action. A tendon-to-bone attachment rather than an easier tendon-to-tendon suture is important for the best results. We have seen no abnormalities of growth of the

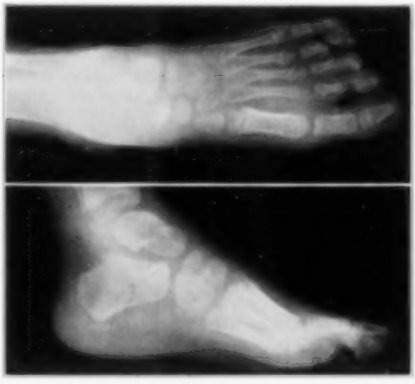

FIG. 9-A

FIG. 9-B

Figs. 9-A to 9-E: Case L. R. Two years and nine months after transfer of tibialis anterior into heel. This patient had poliomyelitis at eighteen months of age. Residual muscle power: gastrocnemius and soleus, *zero*; lateral stabilizers, toe extensors, and tibialis anterior, *good*. Tibialis anterior was transferred into heel at four years of age.

Fig. 9-A: Roentgenograms of foot operated upon.

Fig. 9-B: Roentgenograms of the unaffected foot.

FIG. 9-C

FIG. 9-D

FIG. 9-E

Fig. 9-C: Satisfactory alignment of the foot has been maintained.

Fig. 9-D: Foot operated upon can be dorsiflexed to more than a right angle.

Fig. 9-E: With unaffected foot elevated, the patient can rise on toes of the foot operated upon.

apophysis following this method of fixation. The tendon is sutured so that it is just taut with the foot in maximum plantar flexion. Plaster immobilization is maintained for six weeks and brace protection afterwards for three to four months.

RESULTS

The tibialis anterior has now been transferred according to the technique described above in fourteen patients who had residual paralysis of the triceps surae following poliomyelitis. In two patients, the operation was performed too recently to permit evaluation. The results of the twelve cases included in this study are tabulated in Table I. The average age at the time of the acute attack of poliomyelitis was 3.4 years, the youngest patient being eighteen months old and the oldest being seven years old. The average age at the time of the tendon transposition was 6.5 years; the youngest being three years and four months and the oldest twelve years. The average length of follow-up of the cases

reported has been three years. So far we have not operated upon a patient who has not had good long toe extensors. Drop-foot following the operation has, therefore, not been a complication, and in no instance has a contracture developed which has prevented the patient from getting the heel to the floor in a normal manner.

The end results were classified as follows:

Excellent, the patient is able to walk on his toes and the foot is maintained in good alignment;

Good, the talipes calcaneus is controlled, the patient being able to walk on his toes, but a significant valgus deformity or hyperextension of the great toe has developed;

Fair, the talipes calcaneus is controlled but the patient is not able to walk on his toes;

Poor, failure to control the talipes calcaneus.

According to this classification in seven of the patients an *excellent* result was obtained; three results were *good*, and two were *fair*. Both of the *fair* results (Patients B. L. and P. S.) were in cases in which the tibialis anterior was not sufficiently strong. This was recognized before the operation but even though a good push-off was not restored, a severe talipes calcaneus was prevented. Not all patients, of course, can be expected to walk on tiptoe. There are border-line cases in which there may be some doubt as to sufficient strength in the tibialis anterior for transference, but a reasonably good muscle strength should prevent talipes calcaneus and serve the purpose of the operation. It is also to be noted that in Case P. S. the tibialis anterior was attached to the split tendo achillis instead of into the calcaneus. This is not as satisfactory as insertion into bone.

Although increasing valgus deformity, cock-up of the great toe, depression of the first metatarsal head, and equinus deformity were anticipated, these have not been a serious problem. In five of the twelve patients an excellent alignment of the foot was maintained following transfer of the tibialis anterior alone; three patients had had triple arthrodesis prior to tendon transfer; one patient required a triple arthrodesis and transposition of the extensor hallucis longus; two patients required transposition of the extensor hallucis longus; and in one patient moderate valgus deformity is developing which will require triple arthrodesis for correction. It is entirely possible that in later years valgus deformity and hyperextension of the great toe will develop in more of these patients, but it has become apparent that at least a small percentage of these patients will maintain such satisfactory balance that triple arthrodesis may be avoided. We have been surprised that the indication for arthrodesis has not already become apparent in more of these patients. If one were sure that an arthrodesis would be necessary and if the tibialis posterior and peroneals were normal, one might argue that transposition of these muscles into the heel rather than the transposing of the tibialis anterior would ultimately result in a stronger foot. In our experience, however, the tibialis anterior alone has given better power of plantar flexion than the combined peroneals and tibialis posterior. Five of the twelve patients who have had the tibialis anterior transfer can raise the opposite foot from the floor and then rise on the toes on the affected side without assistance. We believe this to be the ultimate test for satisfactory transfers to correct paralytic talipes calcaneus.

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2. Peabody, C. W.: Tendon Transposition. An End-Result Study. J. Bone and Joint Surg., **20**: 193–205, Jan. 1938.

Some Applications of the Functional Anatomy of the Ankle Joint

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Diastasis of the tibiofibular syndesmosis and the ensuing widening of the ankle-joint mortise is one of the most frequent, complicating factors in fractures of the ankle joint. Persistence of this state after treatment of the fracture frequently accounts for residual complications.

Bonnin has given an outstanding description of the anatomical landmarks about the ankle and of the anatomy of injuries to that joint. He has repeatedly emphasized the importance of examining for diastasis when diagnosing ankle-joint injuries and has described anatomical criteria for the evaluation of the state of the ankle-joint mortise, such as the presence of a clear space between the talus and the medial or the lateral malleolus.

Diastasis may be very difficult to recognize, often because of its tendency to spontaneous reduction, and, when recognized, it may be very difficult to reduce and to keep reduced without open surgery. Routine roentgenograms of the ankle may fail to reveal the diastasis, but frequently it can be demonstrated by strain roentgenograms or under anaesthesia. The presence of diastasis with widening of the ankle-joint mortise assumes greater significance when it is realized that its presence must necessarily mean injury to the medial or lateral group of ligaments of the ankle as well as tearing of the ligaments of the syndesmosis. This fact increases the desirability of recognizing the condition early. Evidence gained from the studies to be described indicates that when one is able to demonstrate damage to the ligaments of the syndesmosis and an actual separation of the malleoli, often such an important structure as the deltoid ligament of the ankle has been injured. Diastasis of the syndesmosis without fracture of the tibia or fibula is possible but rare. Its tendency to spontaneous reduction may account for the infrequent recognition of this lesion without fracture. As when accompanied by fracture of the ankle, diastasis without fracture also indicates damage to the medial or lateral group of ankle-joint ligaments.

ANATOMY

It is the purpose of this presentation to investigate the anatomy and function of the ligamentous structures of the ankle and to correlate these findings with clinical observations given in case reports.

In reviewing the anatomy of the ankle joint, one is impressed by the number of groups of ligaments and the large number of smaller ligaments which make up each of these groups. Charpy and Nicolas considered that the lateral group of ankle-joint ligaments, the medial group of ligaments, and the ligaments of the syndesmosis each consist of three components.

However, the configuration of these structures would seem to be as described in the following paragraphs.

The lateral group of ankle-joint ligaments consists of the anterior talofibular ligament, the calcaneofibular ligament, and the large, strong posterior talofibular ligament.

The deltoid or medial ankle-joint ligament (Fig. 6). Although this ligament is often said to consist of three portions, the anterior, middle, and posterior fasciculi (or more specific-

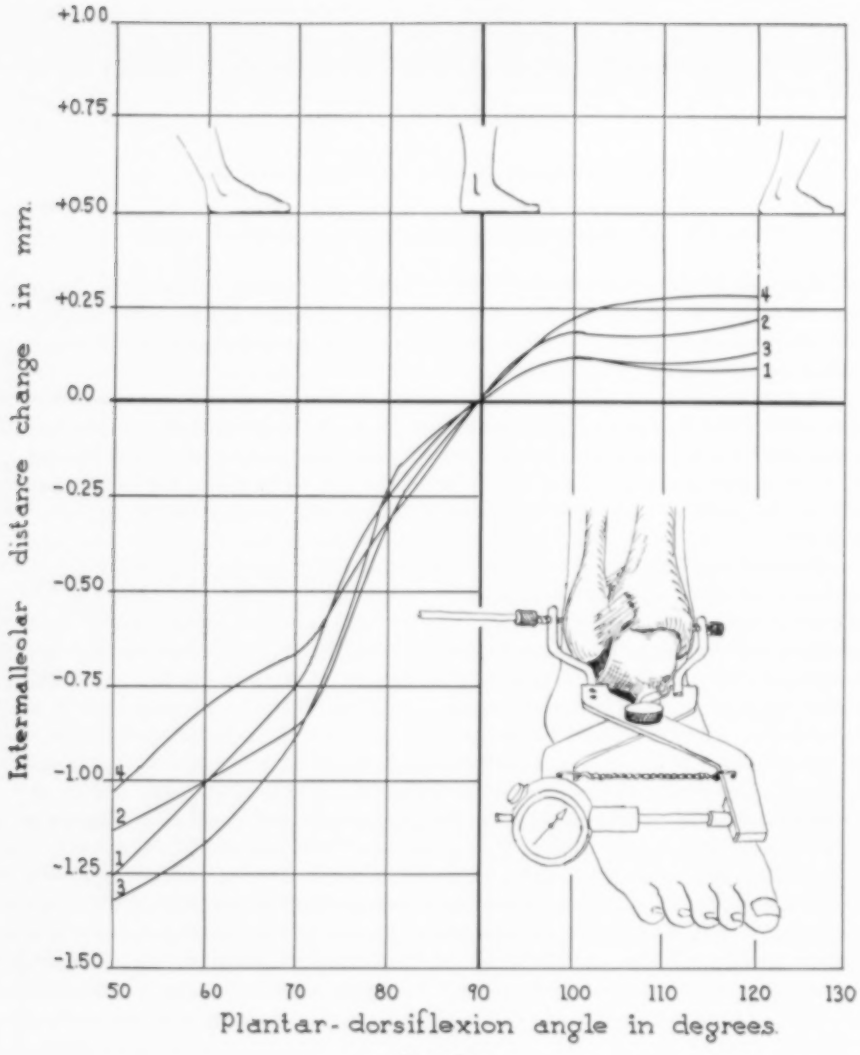

CHART I

Changes in the intermalleolar distance on dorsiflexion and plantar flexion of the foot. (By permission: Artificial Limbs Research Project, University of California, Berkeley, California.)

ally the anterior talotibial fibers, the calcaneotibial fibers, and the deep posterior talotibial fibers), actually there is no division between the anterior and middle fasciculi and it would seem preferable to consider the deltoid as being composed simply of superficial and deep fibers.

The superficial fibers of the deltoid ligament take origin at the tip of the anterior colliculus of the medial malleolus and have widespread attachments which include portions of the navicular, the neck of the talus, the "spring" ligament (plantar calcaneonavicular ligament), and the sustentaculum tali. A few of its fibers attach on the nonarticular portion of the medial aspect of the body of the talus but most of this area is reserved for the talar attachment of the deep portion which originates in a groove between the colliculi of the medial malleolus. Figure 6 is a drawing of this structure based on ob-

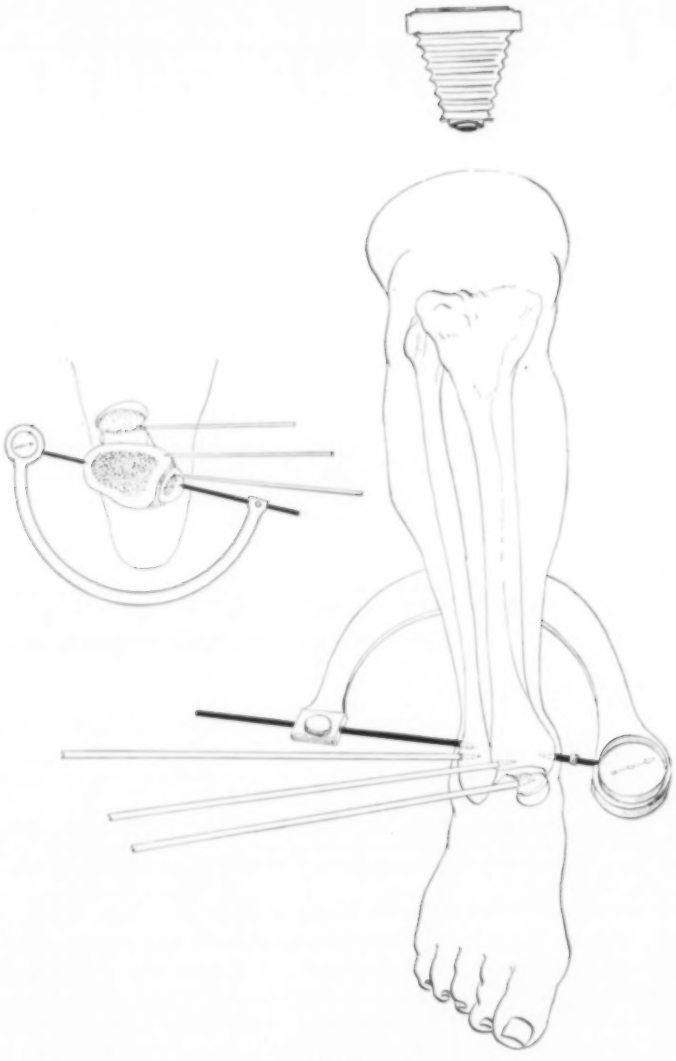

FIG. 1

Apparatus for recording changes in the intermalleolar distance and rotation at the ankle and the syndesmosis.

servations made on twelve dissected fresh specimens. In both the medial and lateral groups of ankle-joint ligaments, the deep posterior portions have the greatest thickness.

The ligaments of the syndesmosis consist of *four* main structures: the anterior inferior tibiofibular ligament, the interosseous ligament, the posterior inferior tibiofibular ligament, and the inferior transverse ligament. The middle portion or the interosseous ligament is the largest and strongest of these four components. The function of these ligaments of the syndesmosis is to secure the fibula against the tibia in the peroneal groove of the tibia (Fig. 7). This groove is bounded anteriorly and posteriorly by the distal tibial tubercles. The depth of this groove varies greatly as a result of individual variation in the size of the distal tibial tubercles. This individual variation, which often makes it impossible to perceive diastasis in routine roentgenograms, has been thoroughly discussed by Bonnin.

CHART III

Rotation at the ankle and syndesmosis produced by medial rotation of the foot after progressive sectioning of the various structures.

CHART II

Rotation at the ankle and syndesmosis produced by lateral rotation of the foot after progressive sectioning of the various structures.

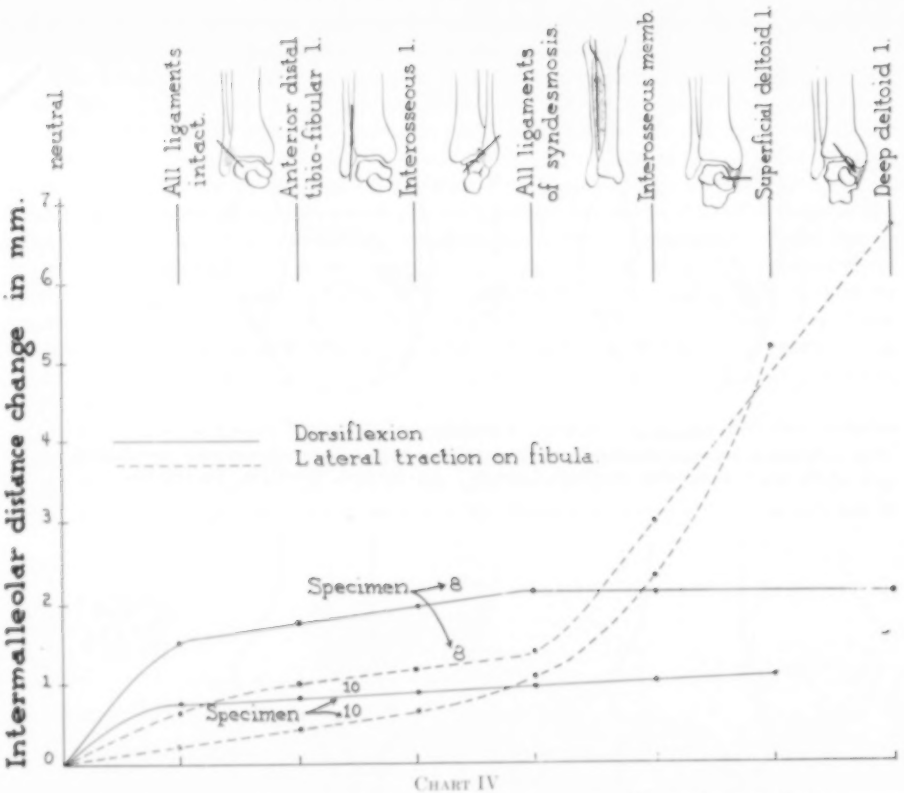

CHART IV

Degree of diastasis produced by progressive sectioning of the ligaments of the syndesmosis, the interosseous membrane, and the deep and superficial portions of the deltoid ligament. The numbers on each curve refer to the specimen which was analyzed, the data of which are recorded by means of the curve.

The three sets of ligaments which have been described serve to maintain the stability of the ankle-joint mortise and the relationship of the talus to the mortise. The tension in all these ligaments is such that if the ligaments of the syndesmosis are stretched, at least one set of the ankle-joint ligaments must also be stretched. This condition is demonstrated by the experiments which are to be described.

FUNCTIONAL ANATOMY OF THE ANKLE JOINT

Although the distal end of the fibula is securely bound to the tibia by the ligaments of the syndesmosis, certain motions of this bone can be demonstrated.

As the talus is dorsiflexed in the ankle-joint mortise, a gradual increase in the distance between the malleoli is produced. This change in intermalleolar distance, although small, is of remarkable consistency and occurs in fairly regular increments (Chart I). The average increase in intermalleolar distance is one and one-half millimeters as the foot goes from full plantar flexion to full dorsiflexion [3]. A very small amount of rotation of the fibula with respect to the tibia about the long axis of the leg (Chart II and Chart VI) can be observed on plantar flexion and dorsiflexion of the foot or in medial and lateral rotation of the leg on the foot. Slight translation of the fibula along its long axis as well as some forward and backward displacement have also been referred to in the literature [2], but in the opinion of the author these displacements have never been accurately measured. It is probable that, during most of the normal actions of the ankle joint, motion of the fibula

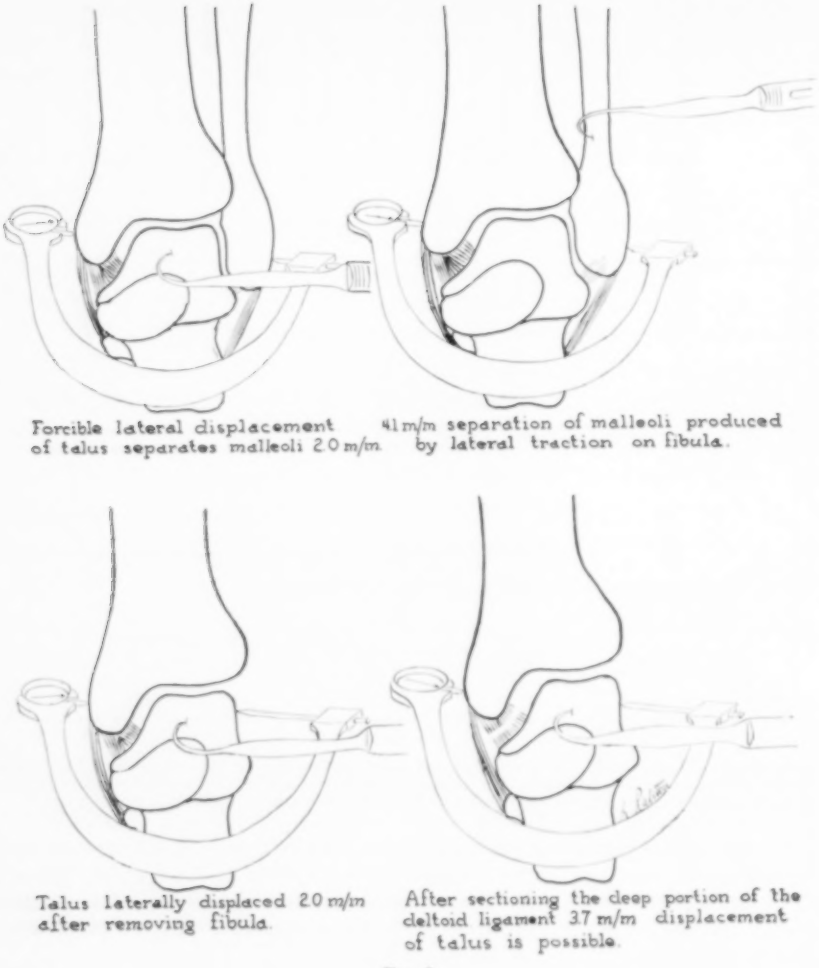
Forcible lateral displacement of talus separates malleoli 2.0 m/m
4.1 m/m separation of malleoli produced by lateral traction on fibula.
Talus laterally displaced 2.0 m/m after removing fibula.
After sectioning the deep portion of the deltoid ligament 3.7 m/m displacement of talus is possible.

FIG. 2

Specimen 9 after sectioning of all of the ligaments of the syndesmosis and the interosseous membrane (as indicated by the absence of these structures in the drawing).

on the tibia includes each of these components.

The presence and magnitude of rotation at the ankle joint in the horizontal plane was studied at the University of California at the Prosthetic Devices Research Project [3]. A small amount of rotation was demonstrated during normal walking. As active or passive dorsiflexion takes place at the ankle, there is a definite tendency for the tibia to be rotated medially on the talus. The magnitude of this rotation may be 5 to 6 degrees. This rotation is reversed as the ankle is plantar flexed. Also, during the stance phase of normal walking, as the foot becomes firmly fixed on the walking surface, there is a definite rotation of the leg on the foot in the horizontal plane. A considerable amount of this rotation is provided by the ankle joint (5 to 6 degrees). Whenever this rotation occurs, there is an accompanying change in the intermalleolar space. Rotation at the ankle in the horizontal plane, as well as dorsiflexion, thus depends upon the elasticity of the ligaments of the syndesmosis

and probably of the lateral and medial groups of ligaments of the ankle-joint. This elasticity allows the malleoli to separate slightly during the movements.

The trochlea of the talus is generally considered to be wedge-shaped when viewed from above. This is said to account for both the looseness (or "play") of the talus in the ankle-joint mortise when the foot is in plantar flexion and for the tightening of the talus in the ankle-joint mortise as the broader anterior portion of the trochlea engages in the mortise during dorsiflexion of the foot. Studies performed at the University of California Prosthetic Devices Research Project [3] did not demonstrate this looseness of the talus in the ankle-joint mortise during plantar flexion of the foot. By means of pins placed in the neck of the talus and in the lateral and medial malleoli, it was demonstrated repeatedly that rotation of these bones at the ankle joint in the horizontal plane was no greater during plantar flexion than during dorsiflexion. Is this stability of the talus in the mortise due to tightening of the lateral group of ligaments of the ankle joint during plantar flexion at the ankle, or is it the effect of the rotatory motion of the tibia or fibula at the ankle joint?

Chart I demonstrates that the intermalleolar distance increases in fairly regular increments as the foot is dorsiflexed in the living subject. This finding indicates that constant pressure is exerted on the sides of the talus by the malleoli. Inspection of the dissected, fresh ankle specimen also reveals that the articular surfaces of the malleoli are in

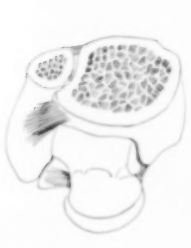

FIG. 3

FIG. 4

Fig. 3: Sectioning of the distal anterior tibiofibular ligament permits lateral rotation and slight backward displacement of the fibular malleolus without increase in the intermalleolar distance.

Fig. 4: The position of the talus in the ankle-joint mortise (left) in plantar flexion and (right) in dorsiflexion.

close contact with the sides of the talus throughout the total arc of motion of the talus in the ankle-joint mortise. Furthermore, the physiological limit of separation between the malleoli is only one to two millimeters which is much less than the difference between the transverse dimensions of the anterior and posterior portions of the trochlea of the talus which may be as much as 4.7 millimeters. This is understandable when it is realized that during the full range of motion of the talus in the ankle mortise no point on the tibial articular surface moves along more than one-half of the length of the trochlear surface (Fig. 4).

As the foot moves from dorsiflexion to plantar flexion, the anterior or leading edge of the tibial articular surface never leaves the anterior broader half of the articular surface of the talus. During this motion of plantar flexion some external rotation of the tibia and fibula takes place on the talus, for the medial malleolus is relatively fixed and traverses a shorter distance along the trochlea of the talus than does the lateral malleolus. If a series of lines are drawn on the trochlea of the talus to represent the intermalleolar line in various positions of dorsiflexion and plantar flexion, it will be seen that the lines made in maximum dorsiflexion and maximum plantar flexion intersect at a point four to five inches medial to the ankle joint forming an angle of 5 to 6 degrees. This angle represents the amount of rotation in the horizontal plane which occurs at the ankle joint during movement from

dorsiflexion to plantar flexion. The lengths of these lines from malleolus to malleolus represent the intermalleolar distance in various positions of the foot. The change in the length of the lines corresponds to the increase in intermalleolar distance that accompanies dorsiflexion of the ankle.

EXPERIMENTS

The function of the syndesmosis and its ligaments and of the deltoid ligament was studied in ten dissected, fresh specimens obtained from above-the-knee amputations. In all specimens, the osseous and ligamentous structures were intact. On the first five specimens, all musculotendinous structures were also left in place but on the remaining five specimens only the osseous and ligamentous structures were retained. The distance that the syndesmosis spread apart at the malleoli was observed with a dial indicator on a

FIG. 5

The posterior approach to the medial malleolus and the deep portion of the deltoid ligament. Forward retraction of the posterior tibial tendon exposes the deep and middle portions of the deltoid ligament.

C-clamp pinned to the malleoli and the amount of rotation of the fibula on the tibia at the syndesmosis and of the tibia on the talus at the ankle joint was recorded by means of Steinmann pins placed horizontally in the talus, fibula, and tibia (Fig. 1). With such an experimental arrangement the following observations were made:

1. The intermalleolar distance changes as the ankle is subjected to various motions.
2. There is rotation of the fibula with respect to the tibia as the leg is rotated medially and laterally with the foot in a fixed position (Charts II and III).
3. There is rotation of the tibia with respect to the talus during the medial and lateral rotation of the leg with the foot in the fixed position.
4. There is rotation in the horizontal plane of the fibula with respect to the tibia

Chart V: Degree of diastasis produced by progressively sectioning the various ligaments of the syndesmosis, the interosseous membrane, and the deep and superficial portions of the deltoid ligaments.

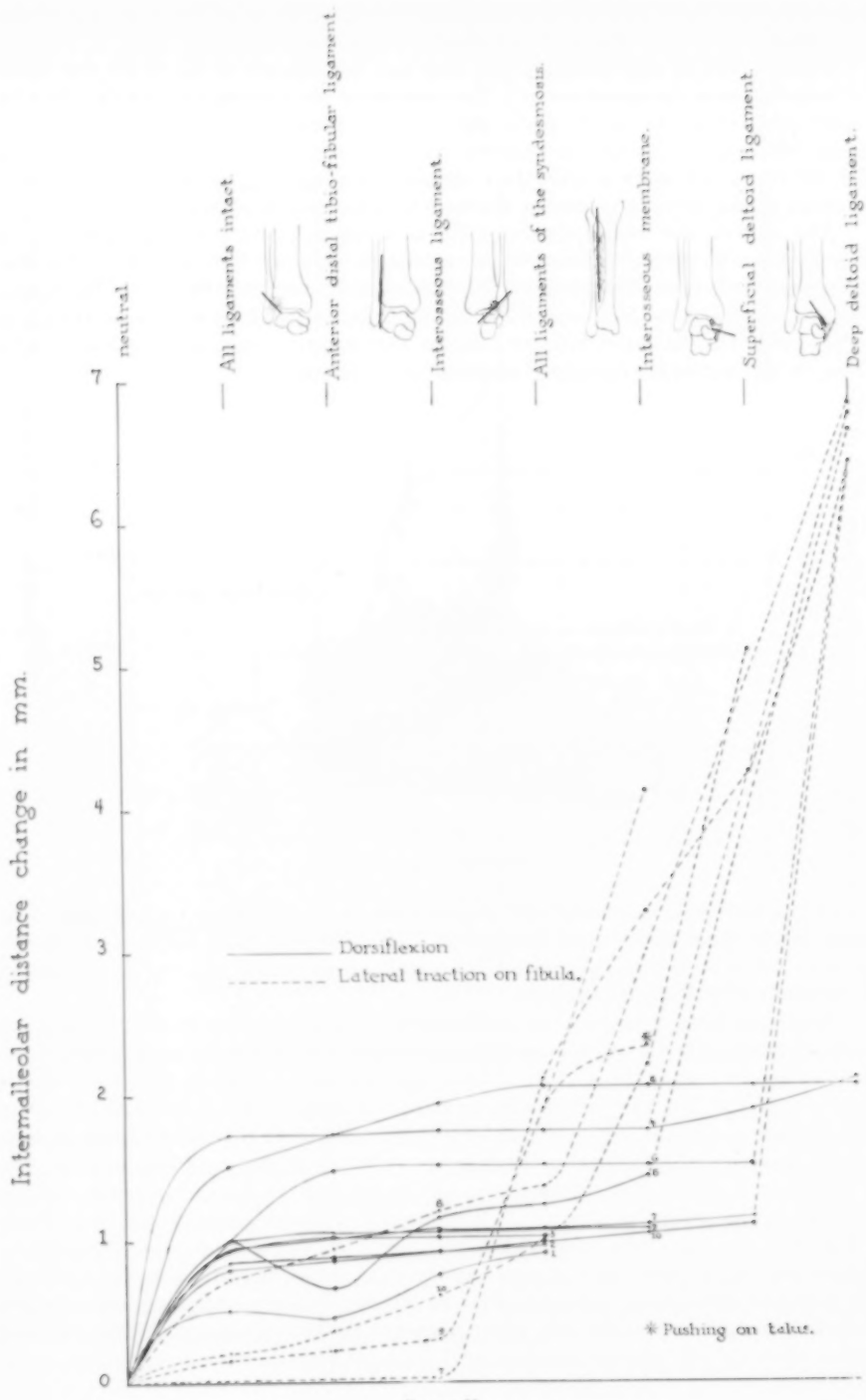
All ligaments intact
Anterior distal tibio-fibular ligament.
Interosseous ligament.
All ligaments of the syndesmosis.
Interosseous membrane.
Superficial deltoid ligament.
Deep deltoid ligament.
neutral
Intermalleolar distance change in mm.
0
1
2
3
4
5
6
7
Dorsiflexion
Lateral traction on fibula.
* Pushing on talus.

CHART V

and similar rotation of the tibia with respect to the fixed talus as motion in the ankle joint takes place from plantar flexion to dorsiflexion of the foot (Chart VI).

This rotation of the tibia about its long axis with respect to the fibula was called "tibial rotation at the syndesmosis". The rotation of the tibia about its long axis with respect to the talus was called "tibial rotation at the ankle". This latter rotatory motion during dorsiflexion is difficult to measure, since it involves observation of parts moving with respect to each other in more than one plane. The values given for tibial rotation at the ankle during dorsiflexion should therefore be considered approximations.

The observations were made first with the specimen intact and then repeated each time after certain critical ligamentous structures of the ankle were sectioned. Measurements were made from photographs of the specimens. In each case, the axis of the camera lens was parallel to the long axis of the leg. The camera was kept as close to the leg as possible (Fig. 1). The angles between the pins were measured with drafting instruments. These measurements are considered accurate to 0.1 degree.

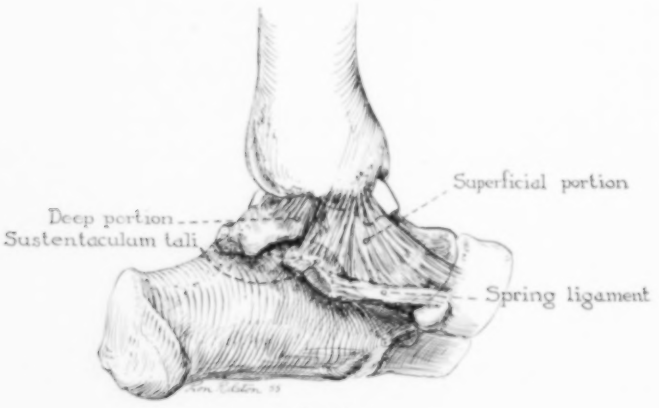

FIG. 6
The deltoid ligament.

In the first three specimens, the observations were recorded as the individual ligaments of the syndesmosis were sectioned progressively, the distal anterior tibiofibular ligament was divided first, then the interosseous ligament, and finally the distal posterior tibiofibular and transverse ligaments.

Specimens 4 and 5 were studied with respect to the ability of the malleoli to separate when subjected to lateral traction as well as dorsiflexion. The ligaments of the syndesmosis, the interosseous membrane, and the deltoid ligament were sectioned, in order. Tests of Specimens 6, 7, 8, and 10 were the same as those performed on Specimens 4 and 5, except that in these specimens, the deep and superficial portions of the deltoid ligament were isolated and divided individually. Tests were made following the division of each part. In Specimen 9, the deltoid ligament was left intact and the fibula was removed. This provided an opportunity to observe the function of the deltoid ligament directly as shown in Figure 2. The talus was then held in place only by the intact deltoid ligament; the greatest separation that could be produced between the talus and the medial mallelous was only two millimeters, indicating that an increase in the medial clear space greater than that amount is possible only after injury to the deltoid ligament. When the deep portion of the deltoid ligament was sectioned, the talus could be separated from the medial malleolus a distance of 3.7 millimeters.

The rotatory tests, summarized in Charts II and III, were done only on the first

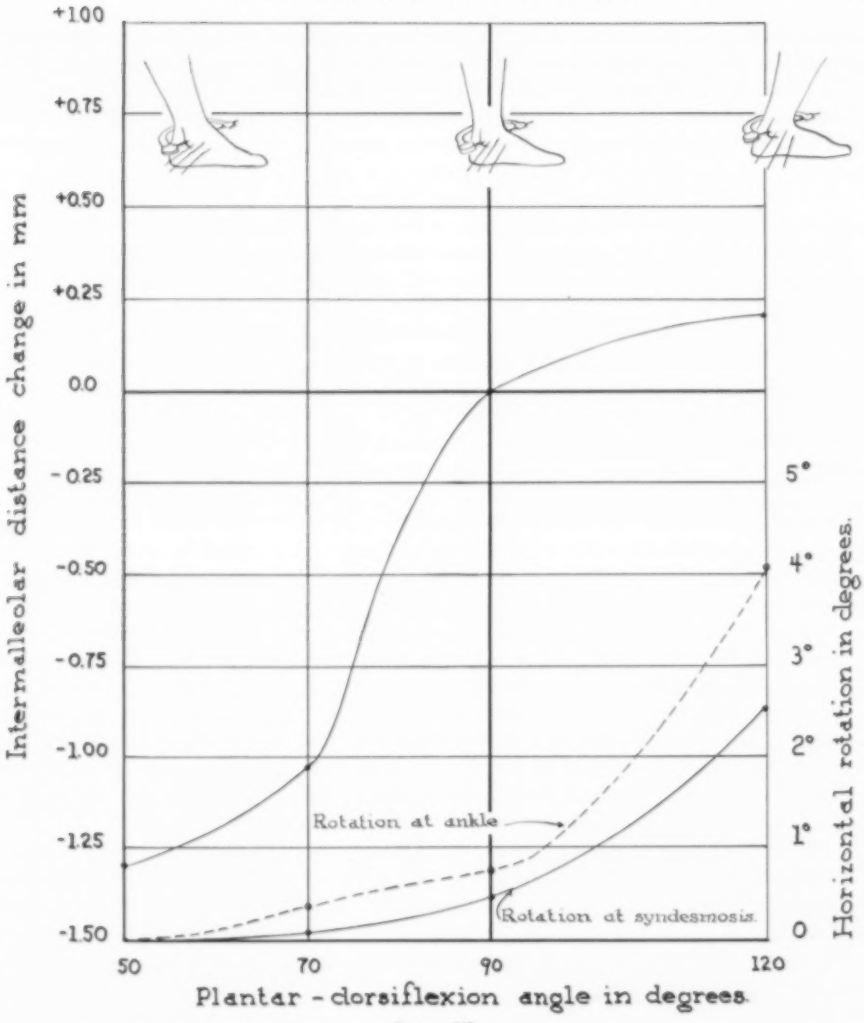

CHART VI

Rotation at the ankle and at the syndesmosis and the change in the intermalleolar distance on dorsiflexion of the foot.

three specimens. To produce lateral rotation of the foot, the leg was actually rotated medially on the fixed foot in order to simulate the mechanism of injury from this movement, as it occurs in the living subject. Conversely "medial rotation of the foot" was performed by rotating the leg laterally on the fixed foot.

In each specimen, the change in intermalleolar distance was also recorded on forceful medial and lateral rotation, abduction, and adduction. Each of these maneuvers produced increments in intermalleolar distance substantially smaller than those produced by dorsiflexion. It has been previously shown [3] that weight-bearing has an insignificant effect upon the intermalleolar distance in the normal living subject.

In measuring the change in the intermalleolar distance, it made a great difference at which position on the lateral malleolus the point of the C-clamp was placed. This observation was made with several specimens. The change in the intermalleolar distance in

dorsiflexion was measured at the level of the ankle joint and comparative readings were taken at the posterior and anterior edges of the lateral malleolus. In one case the intermalleolar distance increased .8 millimeter on dorsiflexion when the pin was placed posteriorly and 1.5 millimeters when placed anteriorly. In another specimen, the posterior measurement was .6 millimeter and the anterior measurement 1.0 millimeter. In a third specimen, the measurements were 1.5 millimeters posteriorly and 2.0 millimeters anteriorly. Therefore, in measuring the changes in Specimens 1 through 10, care was taken to place the lateral pin in the mid-portion of the lateral malleolus.

The difference in intermalleolar-distance change at different positions on the lateral malleolus is, of course, explained by the lateral rotatory motion of the lateral malleolus with respect to the tibia as dorsiflexion takes place. This rotation can easily be demonstrated by placing parallel horizontal Steinmann pins in the lateral malleolus and the lower end of the tibia. In Chart VI, rotation at the ankle joint as well as rotation at the syndesmosis is plotted against the angle of dorsiflexion and compared with the change in intermalleolar distance as dorsiflexion takes place. The measurements in Chart VI were made on a fresh specimen and checked on a normal living subject with comparable results.

RESULTS

These experiments repeatedly demonstrated that individual sectioning of the ligaments of the syndesmosis (Charts IV and V) had only a slight effect on the ability of the malleoli to separate. Sectioning of all of the ligaments of the syndesmosis and of the interosseous membrane produced only a slight increase in the intermalleolar distance. It was not until the deltoid ligament had been sectioned that there was any remarkable increase in the distance between the malleoli. Even after this structure was sectioned in those specimens where the musculotendinous system was intact, only certain stresses produced diastasis of an amount sufficient to be demonstrable by roentgenograms. One can therefore say that in diastasis with or without fracture there must be significant injury to the medial or lateral groups of ankle-joint ligaments. One is impressed by the large amount of damage which must be inflicted upon the ligaments of the ankle in order to produce any recognizable diastasis.

As demonstrated by Specimens 1, 2, and 3 (Charts II and III), progressive sectioning of the ligaments of the syndesmosis results in an increasing ability of the fibular malleolus to rotate laterally when the foot is rotated laterally on the fixed leg. Division of the distal anterior tibiofibular ligament alone increases this lateral rotation of the fibula substantially, but more significant is the appearance of posterior displacement of the lateral malleolus during this maneuver (Fig. 3). Anteriorly, the syndesmosis is opened up and the fibular malleolus slips backward slightly, but no significant increase in the intermalleolar distance is recorded (Charts IV and V). However, as the talus rotates laterally against the lateral malleolus following progressive sectioning of the ligaments of the syndesmosis, tension is exerted on the fibers of the deltoid ligament (Fig. 3). The intact deltoid ligament will then permit the clear space between the talus and the medial malleolus to widen only two millimeters (Fig. 2). Thus, in injuries to the ligaments of the syndesmosis with or without fracture of the lateral malleolus, widening of the medial clear space greater than this amount indicates injury to the deltoid ligament. Often the extent of such injury is not apparent unless there is occasion to test the injured ankle with the patient under anaesthesia.

If all of the ligaments of the syndesmosis and the interosseous membrane are sectioned, marked posterior displacement of the lateral malleolus amounting to four to five millimeters can be produced by lateral rotation of the talus. This maneuver, which is also considered to duplicate the force which produces injury to the ankle most frequently, may be one of the most effective tests for evaluating the extent of injury to this joint.

Anatomically, the lateral malleolus is much more susceptible to posterior displace-

FIG. 7-A

FIG. 7-B

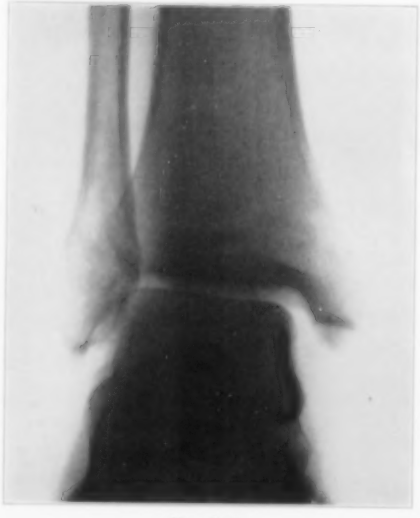

FIG. 7-C

FIG. 8-A

Fig. 7-A: Case 1, roentgenogram of an oblique fracture of the lateral malleolus with diastasis, showing the laterally shifted talus and injury to the deltoid ligament.

Fig. 7-B: A satisfactory closed reduction was obtained.

Fig. 7-C: The roentgenogram made a year later shows that the reduction had not been maintained. There is residual diastasis, lateral shifting of the talus, and increased length of the deltoid ligament. Considerable disability resulted.

ment than to anterior displacement because of the nature of the groove in the tibia in which the fibula lies. Figure 3, a cross section made just above the ankle joint of a fresh specimen, demonstrates the prominence of the anterior border of the groove as formed by the distal anterior tibial tubercle and the small size of the posterior boundary as formed by the distal posterior tibial tubercle. Posterior displacement of the fibular malleolus following a lateral-rotation fracture is illustrated by Case 11 (Figs. 15-A through 15-D).

Studies by the Artificial Limb Research Project of the University of California [5]

FIG. 8-B

FIG. 8-C

Figs. 8-A and 8-B: Case 3, roentgenograms of an oblique fracture of the lateral malleolus with complete diastasis. The entire deltoid ligament had ruptured and had to be removed from the medial clear space and repaired.

Fig. 8-C: After fixation of the lateral malleolus, an excellent result was obtained.

FIG. 9-A

FIG. 9-B

Case 4, roentgenograms of the open reduction and internal fixation of a trimalleolar fracture with an oblique fracture of the lateral malleolus. There is residual lateral displacement of the talus and weakness of the deltoid ligament. Residual diastasis was the result of failure to transfix the lateral malleolus.

describe the presence of lateral torque, or the outward twisting of the leg on the foot during the stance phase of normal walking. This would produce the effect of rotating the mortise laterally on the talus with resulting abuttment of the distal anterior tibial tubercle on the fibular malleolus. This motion is comparable to medial rotation of the foot on the

FIG. 10-A

FIG. 10-B

Case 5, an apparently uncomplicated oblique fracture of the lateral malleolus.

FIG. 10-C

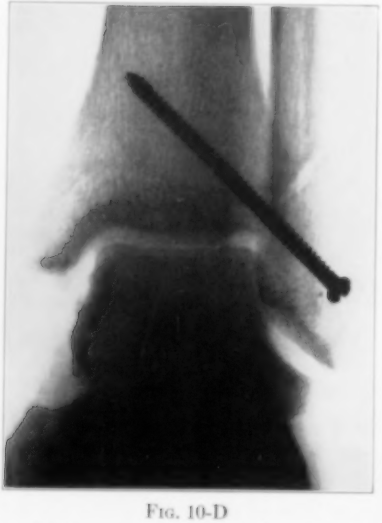

FIG. 10-D

Fig. 10-C: Roentgenogram shows inability to close the medial clear space as a result of interposition of the deep portion of the deltoid ligament. The extent of diastasis and injury to the deltoid ligament was made apparent only after the administration of an anaesthetic and manipulation.

Fig. 10-D: Roentgenogram made after repair of the deltoid ligament and fixation of the lateral malleolus shows the excellent result obtained.

FIG. 11-A

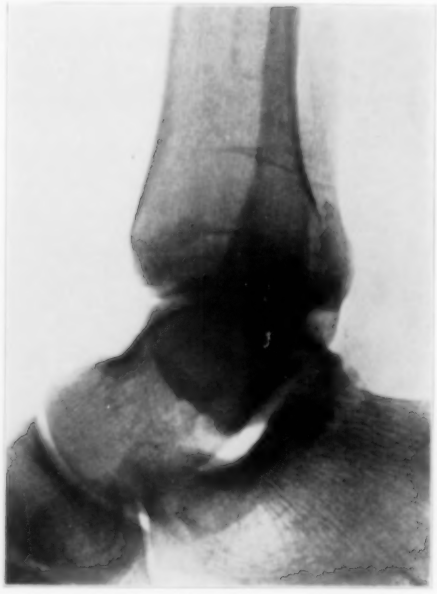

FIG. 11-B

Figs. 11-A and 11-B: Case 6, roentgenograms showing a transverse fracture of the medial malleolus and of the posterior margin of the tibial articular surface. There was also a fracture of the proximal third of the fibula which cannot be seen in this roentgenogram.

Fig. 11-C: Only after administration of an anaesthetic and manipulation was the extent of diastasis appreciated. There was severe damage to the deltoid ligament in addition to the fracture of the medial malleolus.

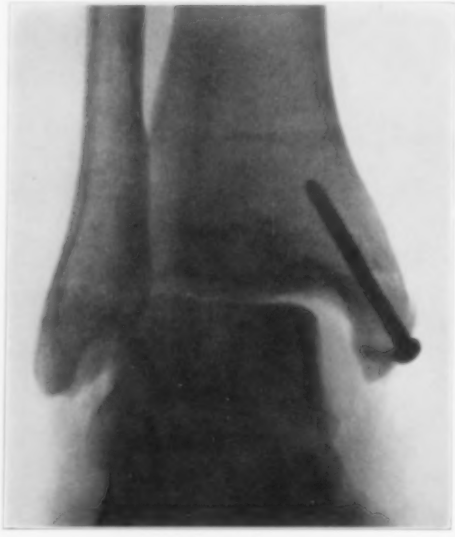

FIG. 11-C

leg. Apparently the ankle can tolerate rather forceful medial rotational strain, a condition present during the normal walking cycle, but the opposite force, lateral rotation of the foot on the leg, is the most frequent mechanism of ankle injury.

DISCUSSION

Roentgenograms of Clinical Cases

Lateral rotation of the foot is considered one of the most common mechanisms of ankle-joint injury. Actually this is medial rotation of the leg on the fixed foot. This produces a fracture by indirect violence. The importance of this lesion has been thoroughly discussed by Bonnin. The simplest form of injury caused by such rotation is a spiral oblique fracture of the fibula at the level of the syndesmosis. In the more severe injury, due to increased lateral force, certain ligaments of the syndesmosis are injured and slight lateral displacement of the talus in the mortise may take place. The most serious injury results when the forced lateral rotation is such that the deltoid ligament is placed under tension (Fig. 3). This structure may then tear, or a fracture of the medial malleolus may result. Because of the

FIG. 12-A

FIG. 12-B

FIG. 12-C

Figs. 12-A and 12-B: Case 8, the roentgenograms show an oblique fracture of the lateral malleolus with marked diastasis and a bone fragment in the medial clear space. Complete rupture of all portions of the deltoid ligament was found.

Fig. 12-C: After repair of the deltoid ligament and fixation of the lateral malleolus, an excellent result was obtained.

tendency of the mortise to resume its normal position spontaneously after such an injury, rupture of the deltoid ligament may easily escape notice.

The fibers of the deep and superficial portions of the deltoid ligament are not in the same plane. Those in the deep portion are more nearly horizontal and are therefore in a position to prevent lateral displacement of the talus. The direction of the fibers of the superficial portion of the deltoid ligament is more nearly in the sagittal plane. In treating this fracture, one frequently has difficulty in accomplishing complete reduction of the medial clear space. This may be difficult even after open reduction and fixation of the lateral malleolus. The deep portion of the deltoid ligament may then be found trapped in the medial clear space. Trapping of the entire deltoid ligament as well as of the posterior tibial tendon in this space has been reported [4, 6]. Inability to achieve an anatomical reduction of the medial clear space by manipulation necessitates open reduction for repair of the injured deltoid ligament.

This repair may be unsuccessful because the torn condition of the deep portion of the structure is not recognized and care is not taken to remove it from the medial clear space. A possible error is to replace the posterior tibial tendon and repair the superficial portion of the deltoid ligament without repairing the deep portion of the deltoid ligament with the result that the medial clear space, as well as the syndesmosis, remains widened. In order to expose the deep portion, a posterior J-shaped incision at the medial malleolus

FIG. 13-A

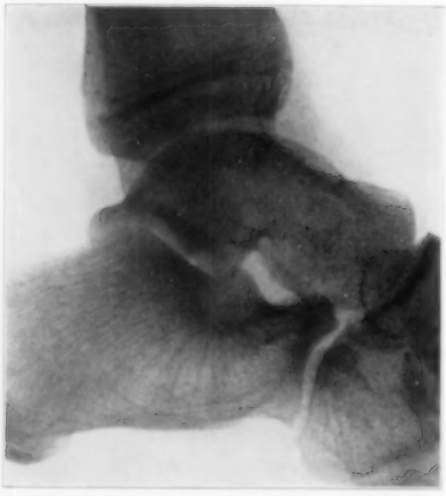

FIG. 13-B

Figs. 13-A and 13-B: Case 9, an old rupture of the deep portion of the deltoid ligament with persistent diastasis and marked disability. The fragment of bone was found to be the talar attachment of the deep portion of the deltoid ligament.

Fig. 13-C: After repair of the deep portion of the deltoid ligament, reduction of the mortise was maintained by transfixion of the fibula. An excellent result was obtained.

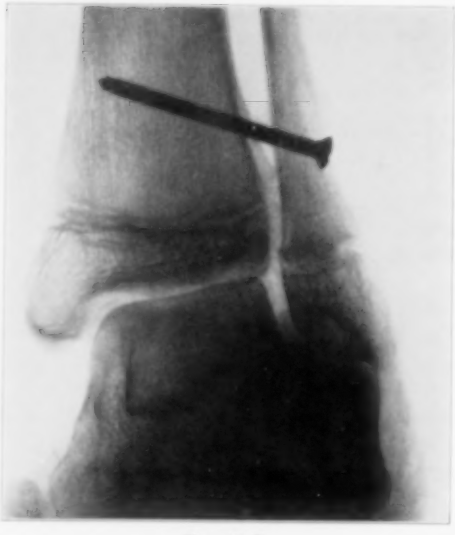

FIG. 13-C

is desirable (Fig. 5). It is only after forward retraction of the posterior tibial tendon, following incision of its retinaculum about the malleolus, that the deep fibers of the deltoid ligament can be properly visualized. This portion extends from the groove between the colliculi of the medial malleolus to the medial side of the body of the talus. Its talar attachment occupies a large area of the non-articular portion of the medial aspect of the body of the talus. The major portion of this structure lies under the superficial part of the deltoid ligament and may escape notice unless a posterior exposure is made with forward retraction of the posterior tibial tendon.

These anatomical considerations are illustrated in Figure 5. In this drawing of a fresh specimen, it may be observed that the sheath of the posterior tibial tendon at the medial malleolus is U-shaped and is actually a retinaculum. It is enclosed in one of the compartments formed by the laciniate ligament which secures the posterior tibial tendon and the flexor tendons at the posterior aspect of the medial malleolus. It has anterior and posterior attachments on the posterior aspect of the medial malleolus, and incision of this structure for retraction of the posterior tibial tendon should not affect the gliding surface of the structure which is closely applied to the tibia. Roentgenograms of Case 9 show a tear of the posterior portion of the deltoid ligament with diastasis of the syndesmosis (Figs. 13-A and 13-B). This injury, which was not recognized for several months, involved

FIG. 14-A

FIG. 14-B

Figs. 14-A and 14-B: Case 10, routine roentgenograms show no apparent abnormality.

Fig. 14-C: After manipulation under anaesthesia, severe damage to the deltoid ligament and the ligaments of the syndesmosis is demonstrated.

FIG. 14-C

a detachment of the posterior or deep portion of the deltoid ligament at its talar attachment. Visualization of the lesion was greatly facilitated by the posterior incision. Cases 3 and 10 (Figs. 8-A and 8-B, 14-A, 14-B, and 14-C) demonstrate complete deltoid ruptures in which replacement and repair were done.

The lateral-rotation injury which causes fracture of the lateral malleolus of the ankle frequently produces partial diastasis and deltoid-ligament injury also, with resulting disturbance of the configuration of the ankle-joint mortise. Only by complete restoration of the mortise can one be sure that the ligaments of the syndesmosis will be restored and that the deltoid ligament will heal at its proper tension. In cases of this type, treatment by closed reduction frequently fails as is evidenced by incomplete final reduction of the lateral malleolus and slight residual increase in the medial clear space. This residual increase in the medial clear space indicates that the deltoid ligament has not healed at its physiological length and that, as is inevitable, some lateral slipping of the talus in the widened mortise has resulted. This imperfection of the mortise can cause a considerable amount of disability as demonstrated by Cases 1 and 4 (Figs. 7-A, 9-A, and 9-B). In the early treatment of such cases one is often justified in placing a metallic screw across the syndesmosis in order to securely fix the fractured fibula in its original position and to restore the medial clear space, as was done in Cases 5, 6, 8, and 9 (Figs. 10-A through 13-C). Frequently this is the only means by which the ruptured deltoid ligament may be held at its

optimum position and tension as it heals. Treating diastasis therefore frequently means treatment for the deltoid lesion. When one realizes that a certain amount of spreading apart of the malleoli and a certain amount of rotation of the fibula about the tibia are anatomical requirements for normal ankle motion the necessity for later removal of such internal fixation becomes obvious. Screws thus placed have been known to break during normal walking after the fractures have healed.

In Case 10, Figure 14-C illustrates the extensive damage to the ankle joint that may

FIG. 15-A

FIG. 15-B

Case 11, a spiral oblique fracture of the lateral malleolus at the syndesmosis with posterior displacement of the fibular malleolus.

FIG. 15-C

FIG. 15-D

Some months after treatment in a plaster cast, there is residual widening of the medial clear space and posterior displacement of the distal end of the fibula.

be present even when conventional roentgenograms show the ankle joint to have a normal appearance (Figs. 14-A and 14-B). The patient, a twenty-two-year-old male, had injured his ankle in a skiing accident but did not recall the precise mechanism of the injury. Only with strain roentgenograms, made with the patient under anaesthesia, was it possible to demonstrate the complete rupture of all of the components of the deltoid ligament and the ligaments of the syndesmosis. The deltoid ligament was repaired through a posterior J-incision, and an excellent result followed.

Case 5 illustrates the lateral rotation fracture of the lateral malleolus with persistent widening of the medial clear space (Figs. 10-A and 10-B). Open reduction was done because of the state of the medial clear space. As demonstrated by the roentgenogram made in surgery (Fig. 10-C), internal fixation of the lateral malleolus did not reduce the mortise because of the deltoid ligament trapped within it, which then had to be repaired.

SUMMARY AND CONCLUSIONS

Certain motions at the syndesmosis of the ankle have been demonstrated. As dorsiflexion of the ankle takes place, the malleoli separate in fairly regular increments, the greatest distance being approximately 1.5 millimeters. The articular surfaces of the malleoli remain closely applied to the sides of the talus throughout the range of ankle motion. The tibia rotates a few degrees medially about its long axis on the talus and the syndesmosis opens anteriorly. There is a relative lateral rotation of the fibula with respect to the tibia. Other motions at the syndesmosis, such as forward or backward displacement or translation of the fibula on its long axis, may occur but they have not yet been demonstrated convincingly.

The syndesmosis permits this flexibility because of the elasticity of its ligaments. The elasticity of these ligaments allows the intermalleolar distance to change and facilitates tibial and fibular rotation which is essential to normal motion at the ankle joint. These motions contribute to the general springiness or elasticity of the system.

Progressive sectioning of the ligaments of the syndesmosis and the interosseous membrane leads to increasing backward mobility and increasing lateral rotation of the lateral malleolus. Loss of these structures, however, produces no significant widening of the medial or lateral clear spaces or increase in the intermalleolar distance. In order to produce widening of the mortise either the medial or the lateral group of ligaments, as well as the ligaments of the syndesmosis and the interosseous membrane, must be divided.

The most common fracture at the ankle is the spiral oblique fracture or lateral-rotation fracture of the fibular malleolus. This is frequently associated with an increase in the medial clear space. When this increase is moderate, partial diastasis is present and there is injury to the deltoid ligament. Marked increase in the medial clear space indicates a complete tear of the deltoid ligament including both deep and superficial portions. Inability to reduce the medial clear space may mean that the deltoid ligament must be removed from the medial joint space and repaired.

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Procedure to Reduce Dislocation of the Shoulder

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Since ancient times, many different procedures have been employed to reduce dislocations of the shoulder [2]; the best known of them are the methods of Hippocrates [5] and Galenus [9].

It is not our purpose to review the literature in detail but to state that in a general way the various procedures proposed may be divided into three main groups [4, 9], as follows:

1. *Methods employing leverage*, in which the upper extremity is used as a first class lever and the orthopaedist's fist or foot serves as a fulcrum in the patient's axilla. Example: Hippocrates' method [12].

2. *Methods employing successive maneuvers*, in which the power of the leverage is not employed, but instead the head of the humerus is manipulated in such a way that it follows the course of the dislocation in the opposite direction. Example: Kocher's procedure [3].

3. *Methods designed to disengage* the dislocated humeral head and to impel it into its normal position by traction and manipulation in wide abduction as in Mothe's [11] procedure or it may be continuous and elastic as in Anger's procedure [4].

Whatever method is employed the fundamental aims are: (a) to overcome the muscular spasm which appears after luxation; (b) to readjust the joint in its normal position, without increasing the damage to the articular structures which is already present as the result of the luxation itself [10].

Of these methods, the one consisting in successive maneuvers without leverage is the most frequently employed, particularly Kocher's maneuver which has been very much used in the last two decades. However, all three methods involve certain risks. In the first one, the force on the fulcrum in the axilla may produce fractures (especially of the neck of the humerus), paralysis, or vascular injuries. The principal risk in the second method is fracture of the neck of the humerus, especially in old patients. In the third method, dangerous compression may result when the head of the humerus is pushed through the soft parts and the tear in the capsule.

There will, of course, always be personal preferences as to method, based on familiarity and training [6, 7, 8].

The procedure to be described in this paper belongs to the second group of methods.

TECHNIQUE OF PROCEDURE

The procedure is performed in three steps: fixation, rotation, and traction. In the following paragraphs, the maneuvers for reducing a dislocation of the right shoulder are described. In the procedure for reducing a dislocation of the left shoulder, the orthopaedist follows the same maneuvers with the opposite hand.

The patient should be lying in the supine position on the table, the involved shoulder projecting over the edge of the table. The orthopaedist stands at the injured side of the patient, facing the head of the table. He holds the patient's right wrist with his left hand in such a way that the patient's injured shoulder is in abduction, the elbow is in 90 degrees of flexion and the patient's forearm is held in the vertical position (Figs. 1 through 5). The patient's involved right upper extremity is now in the position for the fixation.

Fixation

1. Still gripping the patient's wrist with the left hand and holding the extremity

* Service of Prof. Godoy Moreira.

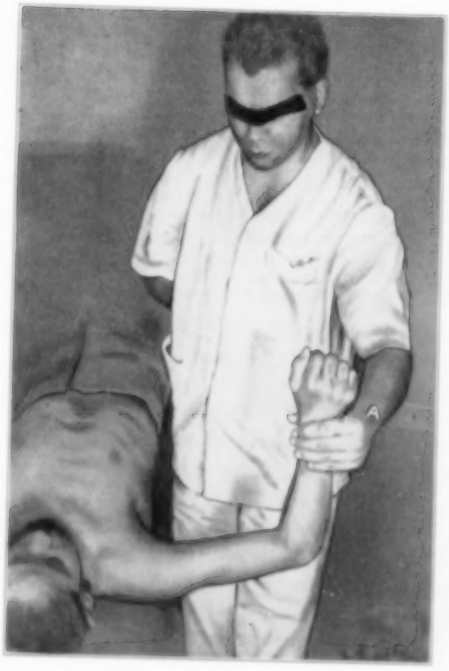

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

Fig. 1: Beginning of procedure. *A*, in the initial position, the orthopaedist grasps the patient's wrist and holds the patient's hand up so that the forearm is vertical.

Fig. 2: Beginning of fixation. *A*, the orthopaedist grasps the patient's forearm in such a way that the patient's arm rests against his own forearm *B*.

Fig. 3: The fixation grip is completed when the orthopaedist holds the patient's arm above the elbow *C*.

Fig. 4: Rotation. *D*, the orthopaedist climbs on the ladder and, *E*, bends over the patient. *F*, the patient is turned on his uninjured side in the three-quarters lateral position.

Fig. 5: Traction. *E*, the orthopaedist straightens his body, lifting the patient. *G*, the patient's forearm is across his body, so that he will not attempt to support himself with his elbow. *H*, the patient's shoulder is in the position of reduction.

in the position for fixation, the orthopaedist thrusts his free right hand under the patient's forearm and grasps the ventral side of the patient's wrist (or the distal third of the forearm). The proximal third of the dorsal surface of the patient's arm rests on the proximal third of the radial aspect of his own arm. Slight traction is exerted (Fig. 2).

2. With his left hand, the orthopaedist reaches beneath the patient's forearm and grasps the patient's arm just above the elbow (Fig. 3).

With this grip, the patient's arm is firmly fixed, making possible the next step.

Rotation

The patient is now asked to turn onto his uninjured side. As the patient does this the orthopaedist (without releasing the fixation grip) steps onto a small stepladder previously placed by the table (Fig. 4). The patient is now in the *three-quarters lateral position*, and the operator is in a crouched position, bending over the patient.

Traction

1. The orthopaedist now stands erect; by this movement, the patient is lifted slightly from the table and turned into the full lateral position. The orthopaedist must caution the patient to relax and not to attempt to support himself. It is a good idea to ask the patient to hold his free arm across his body, so that he will not try to brace himself against the table with it (Fig. 5). In this way, the patient's full weight serves as the traction force. Here, the orthopaedist may help by rotating the arm of the patient laterally with his left hand or by rotating the forearm laterally with his right hand.

2. This position must be maintained for about one minute with the patient completely relaxed. The patient should be warned not to raise his head because this hinders the procedure a great deal by immobilizing the scapula. At the end of this time, the orthopaedist may palpate the shoulder to verify that reduction has occurred; he uses the left hand, while maintaining the position with his right hand, which originally grasped the patient's forearm. In most cases, neither the doctor nor the patient feel or hear the reduction. If the procedure has not been successful, it is repeated and, during the last moments, the orthopaedist assists the reduction. He slides his left hand down to the axilla and assists the head of the humerus into the glenoid. After traction is released, the patient's arm should be brought into exaggerated adduction.

The most common errors in technique are too short a period of traction or inefficient traction. The latter results from failure to lift the patient sufficiently, particularly if he is obese or powerfully muscled; failure on the part of the patient to relax; lack of coopera-

tion on the patient's part with the result that he either raises his head or supports himself with the other hand or elbow.

RESULTS

We have employed this procedure in twenty-four patients (including one who had bilateral dislocation) with acute and recurrent luxations, in patients of different ages and with different types of dislocations *.

In twenty-one cases, reduction was attained with ease on the first attempt. In two patients, one of whom was very muscular and the other very obese, the reduction was not successful on the first attempt and the procedure was repeated several times, after an anaesthetic had been injected intravenously. In the two remaining cases, there were failures by this method, and it was necessary to use an entirely different method in which the humeral head was disengaged by thrusting it forward. In these two patients, the dislocations were complicated by fracture of the greater tuberosity of the humerus.

In summary, the results were as follows:

Reduced dislocations		
Easy reductions	21 (91.3 per cent)	23 (92 per cent)
Difficult reductions	2 (8.7 per cent)	
Failure of reduction		2 (8 per cent)
Total number of cases		25

DISCUSSION

The mechanism of the reduction by this method is as follows:

1. When the operator is standing erect, a position which he can maintain relatively easily for an adequate length of time, constant traction (the patient's unchanging weight) of sufficient force to overcome muscle spasm is maintained. The advantages of using the body weight of the patient for the traction force are that it is constant and that the orthopaedist does not exert traction on the arm in some arbitrary, relatively uncontrolled fashion.

2. The patient himself, by turning from the supine to the lateral position while traction is maintained, accomplishes the rotation necessary to bring the head of the humerus into a proper anatomical relationship with the glenoid. In contrast to most maneuvers which accomplish reduction by rotation of the humerus while the scapula remains fixed, this maneuver is based on the opposite principle, the scapula being rotated on the fixed humerus.

3. When traction has overcome muscle spasm and the correct amount of rotation has been achieved, the muscles surrounding the shoulder joint are under uniform tension and in such a physiological arrangement that the humeral head spontaneously seeks its way back into its normal position through the rent in the capsule.

If capsular interposition occurs and the head of the humerus does not pass spontaneously through the tear in the capsule, the procedure fails. Under these circumstances movement of the head of the humerus may be felt, but there is no ensuing reduction. In this case, traction and rotation are not sufficient, and it will be necessary to push the head of the humerus into the glenoid manually.

The procedure has several advantages. It can be carried out by the orthopaedist alone, without either an assistant or an anaesthetist, since countertraction is not necessary and the procedure is painless. It may be performed without the active cooperation of the patient, if assistants are available to rotate his body. There is no danger of fracture of the surgical neck of the humerus, because rotation is performed and controlled by the patient's own weight. The method avoids the danger of injury to vascular and nervous structures.

* We have had no chance to apply this procedure in a posterior luxation of the shoulder. However, it would also seem possible to reduce a posterior luxation with this maneuver.

Should the procedure fail another method such as pressure on the head of the humerus or some other maneuver may cause reduction.

The disadvantages of this method are that it failed to produce reduction in 8 per cent of the cases; it proved tiresome for the orthopaedist when obese or large patients were treated; and it was, of course, impractical when other injuries existed, such as fractures of the lower extremities, pelvis, and the like.

CONCLUSIONS

1. This procedure for reduction of shoulder dislocation is based on functional and anatomical principles. It can be performed without anaesthesia and without assistance.

2. In twenty-four patients with both acute and recurrent dislocations it has been successful in 92 per cent.

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Fractures of the Proximal Tibial Epiphyseal Cartilage

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Although fractures of the epiphyseal cartilage are common injuries of childhood, involvement of the proximal tibial epiphyseal cartilage is very rare. Few reports of such fractures are to be found in the literature. Gibson, in citing Roberts and Kelly, stated that only twenty-six cases had been reported up to 1916. Hutchinson collected ten cases in 1894. Tanton (1916), as cited by Gibson, reported a single case. The authors have been able to find but three references in the American literature over the past thirty years, single cases being reported by Gibson in 1923, by Curry and Bishop in 1937, and by Aitken in 1938. Recently Jorg Böhler of Vienna has reported three cases of his own and mentions single cases described by Pal in 1932, Henrici in 1935, and Stubenrauch in 1931. The latter also reviewed the literature in 1931 and found only twelve cases [6].

The vulnerability of any epiphyseal cartilage to injury depends upon many factors, chief of which are its anatomical position, its size and shape, and its ligamentous attachments. Most epiphyseal-cartilage fractures are produced by an avulsion force, the epiphysis being pulled off with the epiphyseal plate by a force applied through the attached ligaments. The position of the proximal tibial epiphysis and its size and shape render it just as susceptible to trauma as is the distal femoral epiphysis, yet the latter is more often the site of fracture. The factor which makes the proximal tibial epiphysis less likely to sustain a fracture would therefore seem to be the paucity of its ligamentous attachments. A review of the anatomy indicates that such is the case. In the distal end of the femur, both the fibular and tibial collateral ligaments are attached to the epiphysis and are directly involved in fractures of this structure. However, at the proximal end of the tibia, the fibular collateral ligament has no attachment to the epiphysis while the tibial collateral ligament has only a very small area of attachment to the epiphysis, the major portion of the ligament being attached to the shaft, well below the epiphysis. Both cruciate ligaments are directly attached to the epiphysis but seem to exert little effect upon it in the presence of intact collateral ligaments. Although the proximal tibial epiphysis also carries the direct attachment of the semimembranosus and patellar tendons, neither of these appear to play a part in the mechanism of fracture.

The authors have classified the various types of fractures of the proximal tibial epiphysis cartilage according to the mechanism of injury. This classification, the authors believe, is of some value in the prognosis of possible growth disturbance.

Type I: Avulsion type of fracture resulting from the pull of the attached ligaments. The way in which the entire epiphyseal plate is stripped off the diaphysis is similar to the stripping off of a layer of plywood. The fracture line apparently passes through the zone of active growth where there are degenerating cartilage cells, osteoid tissue, and newly formed bone. Displacement in this type of fracture may be marked, but ultimate deformity, as a result of the displacement, does not occur. Remodelling in response to stress according to Wolff's law ultimately restores the normal shape of the bone, once union of the diaphysis to the epiphysis has occurred. Growth disturbance with deformity in this type is rare as the epiphyseal plate itself is not damaged.

Type II: Compression type of fracture. The fracture line may cross the epiphysis more or less obliquely and emerge between the bony epiphysis and the epiphyseal plate without damage to the latter; in such a case, growth disturbance will not occur. If, how-

ever, the fracture line crosses the plate and emerges between it and the diaphysis, as illustrated, then deformity may occur because of damage to the plate.

Type III: Compression type of injury in which the epiphyseal plate has been crushed between the bony epiphysis and the diaphysis. Deformity is to be anticipated following this type of injury. The fracture line need not be as extensive as that shown in the drawing (Fig. 1); it may only involve a small area of bone on either side of the epiphyseal plate or it may be so small as to be overlooked or considered to be of no clinical or roentgenographic significance.

In reports of cases of fracture of the proximal tibial epiphysis, the trauma is described as being violent and frequently there are other serious injuries. Hutchinson, Aitken, and Böhler each described a case in which the fracture was similar to our first case (Figs. 2-A through 2-J). The fracture line extended through the epiphysis itself, as in a Type II fracture (Fig. 1). In all other cases the epiphysis with the tibial tubercle was avulsed from the shaft usually without fracture of the shaft. All cases showed a typical posterior displacement of the diaphysis, the epiphysis seeming to be anteriorly displaced, a position

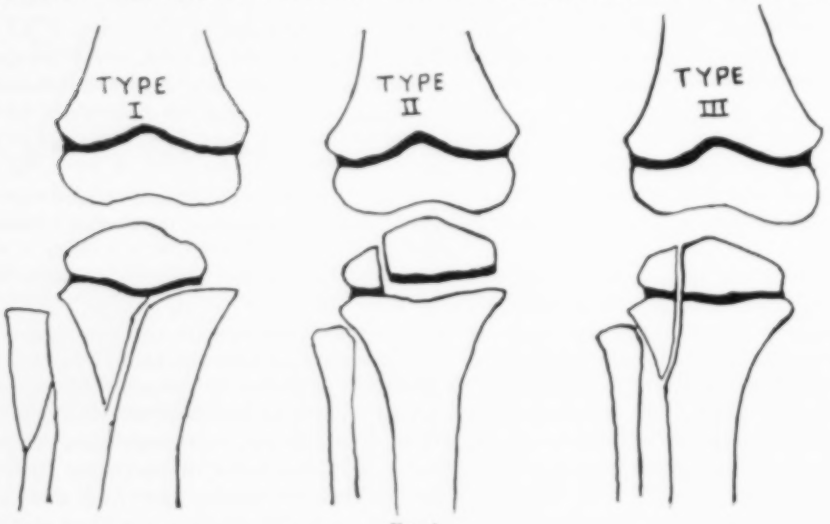


FIG. 1

Three types of fractures of the proximal tibial epiphysis

Type I: Avulsion injury may cause marked displacement but, after reduction and union, deformity and growth disturbance are rare.

Type II: Compression fracture with separation of epiphysis from diaphysis may be difficult to reduce and may result in deformity. If fracture line emerges between epiphysis and epiphyseal plate, growth disturbance will not occur.

Type III: Compression fracture in which epiphyseal plate is crushed. Deformity in this type is common.

referred to in the foreign literature as one of recurvatum [2]. Actually the epiphysis remains in normal relationship to the femoral condyles while the tibial shaft is displaced posteriorly with some degree of either medial or lateral displacement. Pressure of the displaced shaft in the popliteal space frequently produces arterial occlusion which results in the development of gangrene and necessitates amputation[2,3,5]. In many cases, injury which causes these epiphyseal fractures appears to be similar to the injury which causes posterior dislocation of the tibia, that is, either a direct blow on the anterior proximal portion of the tibia with the knee in full extension or forced hyperextension of the knee. Less frequently, the injuring force may be against the medial or the lateral side of the knee, as in Case 1.

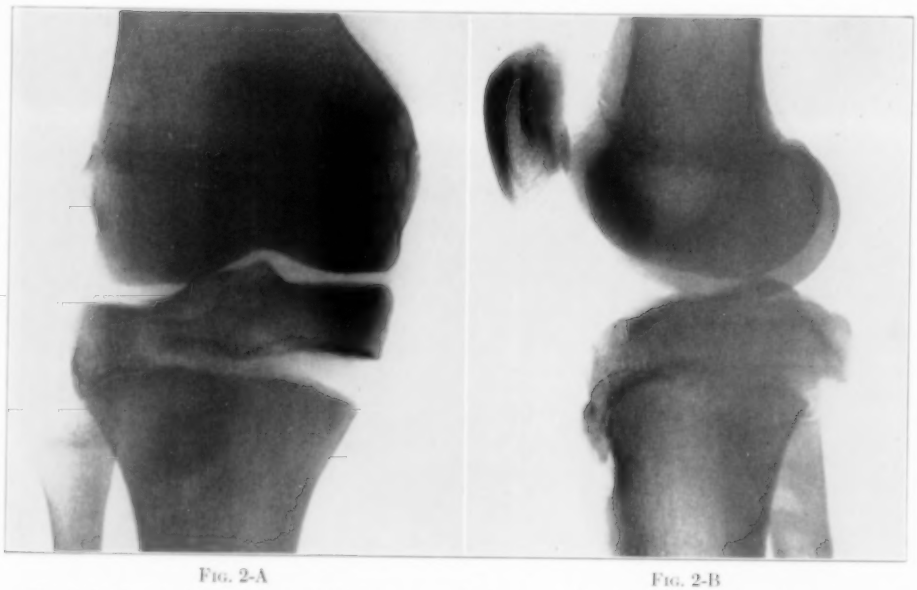


FIG. 2-A FIG. 2-B

Fig. 2-A: Case 1, J. F., June 8, 1949. Anteroposterior roentgenogram showing fracture of the proximal tibial epiphysis with abduction of the diaphysis. The medial side of the epiphysis is tilted upward.

Fig. 2-B: Lateral roentgenogram shows the displaced portion of the proximal tibial epiphysis including the tibial tubercle; the tibial diaphysis is anteriorly displaced on the epiphysis.

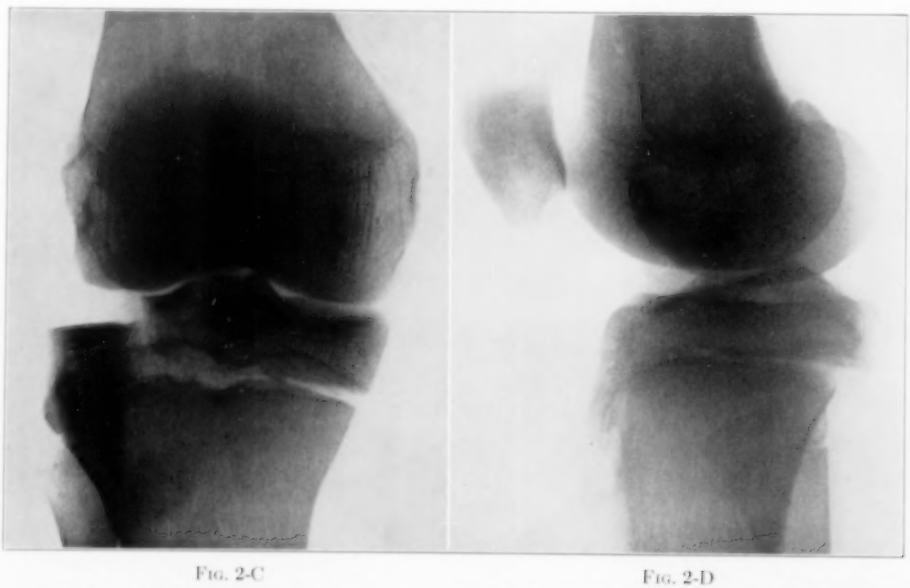


FIG. 2-C FIG. 2-D

Fig. 2-C: June 9, 1949, anteroposterior roentgenogram showing tilting of epiphysis into the joint space.
Fig. 2-D: Lateral roentgenogram showing persistence of the anterior displacement of the shaft.

All reports indicate the instability of these fractures and the difficulty experienced in maintaining the reduction. Usually some degree of posterior displacement persisted, as no form of immobilization in either flexion or extension could maintain the shaft in contact with the epiphysis.

FIG. 2-E FIG. 2-F

Figs. 2-E and 2-F: Roentgenograms made June 17, 1949, showing lateral and anterior displacement of diaphysis. In all roentgenograms, the epiphysis of the tibial tubercle is seen to be attached to the main epiphysis.

FIG. 2-G FIG. 2-H

Figs. 2-G and 2-H: Postoperative roentgenograms showing the epiphysis fixed to the diaphysis but with some persistent displacement.

The following two cases are presented not only because of the rarity of the injury, but also because they present unusual features of this uncommon injury including anterior displacement of the shaft. The first case appears to be similar to those reported by Tanton [4] and Böhler.

CASE 1. On June 8, 1949, while catching in a baseball game, J. F., aged seventeen, was standing in a semicrouched position blocking home plate when a player sliding in from third base struck the medial aspect

FIG. 2-I

FIG. 2-J

Figs. 2-I and 2-J: Roentgenograms made June 24, 1950, one year after injury, showing essentially anatomical position of the epiphysis in the anteroposterior and lateral views as compared with the opposite side. Slight irregularity of the lateral tibial joint surface of the right knee can be seen, but both epiphyses have fused.

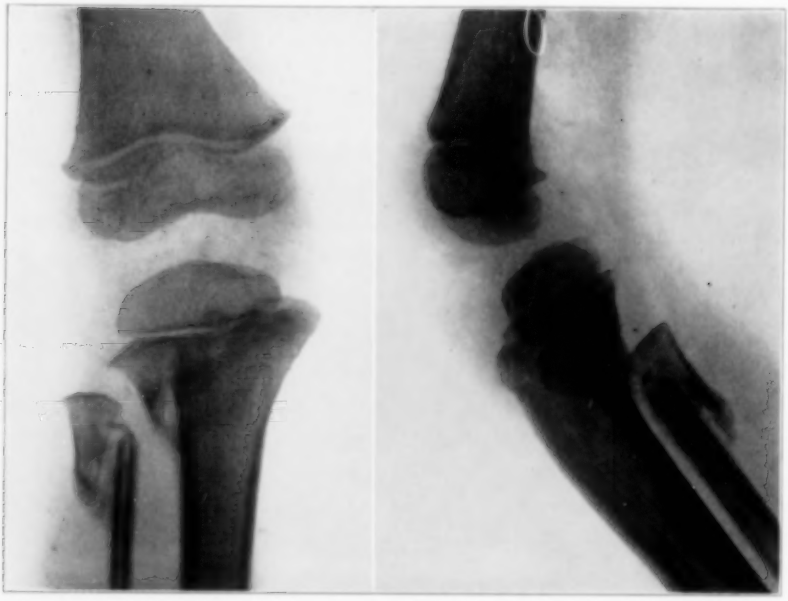


FIG. 3-A FIG. 3-B

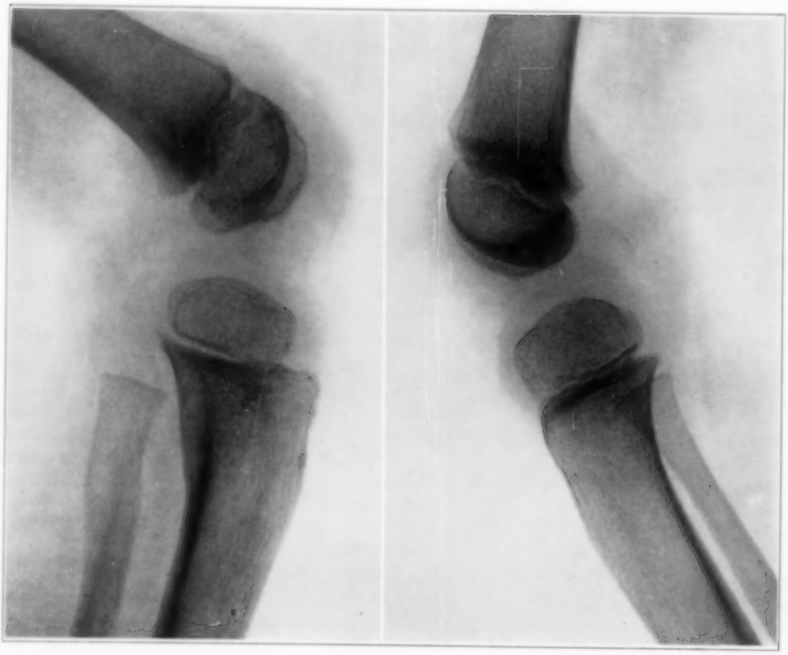
Figs. 3-A and 3-B: Case 2, J. McP. Roentgenograms made August 23, 1950, fifteen days after injury. There is a Type I fracture of the proximal tibial epiphysis. The shaft lies anterior and medial to the epiphysis. There is a large diaphyseal fragment attached to the epiphysis and considerable callus is present about the fractures of the tibia and fibula. No attempt was made at reduction.

of his right leg. He was knocked to the ground and was unable to arise because of pain in the right knee. Roentgenograms revealed a vertical fracture of the proximal tibial epiphysis in its lateral half, the fracture line emerging medially between the epiphysis and the shaft (Figs. 2-A and 2-B). The shaft was abducted on the epiphysis and was displaced anteriorly.

Under pentothal anaesthesia an immediate attempt at reduction was made. The proximal tibial epiphysis could be palpated easily but slipped in all directions from under the finger like a loose body. The lateral displacement of the shaft was easily corrected but the lateral edge of the epiphysis tended to tilt upward into the joint and to become displaced proximally. Reduction consisted of manipulating the shaft in an attempt to catch and hold the elusive epiphysis. After three attempts, satisfactory reduction was obtained and a cast was applied with the knee in slight flexion. Roentgenograms made the following day showed recurrence of the anterior displacement of the shaft and proximal displacement of the epiphysis (Figs. 2-C and 2-D). Temporary reduction was again obtained. It was possible to reduce the fracture completely, but any motion of the leg inside the plaster or in the operator's hands caused the epiphysis to slip out of alignment. Although roentgenograms showed lateral displacement of the shaft at times (Figs. 2-E and 2-F), on manipulation, the epiphysis itself could be seen and felt to displace in all directions. Displacement recurred after repeated attempts at reduction.

On June 27, 1949, open reduction was performed, the cruciate ligaments and the medial meniscus were visualized and appeared to be normal. Even with direct exposure, the fragment was difficult to fix in position as it tended to displace in all planes. Firm fixation was finally obtained but there was still some persistent proximal displacement of the epiphysis (Figs. 2-G and 2-H). Immobilization in plaster was continued until September 13, 1949, after which it was replaced by a walking caliper brace until November 5, 1949. On November 20, 1949, an area of fluctuation developed over the fibular end of one of the bolts. Consequently one bolt and one washer were removed. Although the other washer in the fibular area was not removed, the infection cleared up promptly. The patient thereafter had no further difficulty. When seen on June 1, 1950, he had no complaints. The knee showed hyperextension of 15 degrees and a loss of flexion of 10 degrees. There was still an appreciable amount of lateral instability on abduction of the extended knee. Roentgenograms made at that time showed all the epiphyses to be closed with little evidence of residual displacement. (Figs. 2-I and 2-J). The patient was last seen in September 1952, at which time there was full knee motion and only a slight amount of abnormal lateral mobility.

R Fig. 3-C L



R Fig. 3-D L

Figs. 3-C and 3-D: Roentgenograms made November 7, 1950, three months after injury. The fracture is now completely united. Correction of the valgus deformity is progressing.

R FIG. 3-E L

Anteroposterior roentgenogram made January 31, 1951, five and one-half months after injury. The valgus deformity has almost completely disappeared.

The mechanism of the injury which produced the fracture in this patient can only be postulated. It would appear that the tibial collateral ligament had a firm attachment to the epiphysis and maintained the epiphysis in close relationship to the femoral condyles, although the knee was partially flexed. As the limb was forced into the knock-knee position, the lateral tibial condyle was driven against the lateral femoral condyle which acted as a wedge splitting the tibial epiphysis as the remaining medial ligament attached distal to the epiphysis ruptured. The tibial shaft then was avulsed under the epiphysis and displaced laterally.

Had this injury occurred in a younger individual we believe that such a fracture of the epiphyseal plate and epiphysis would have led to growth disturbance.

This second case is presented as it demonstrates a type of displacement not hitherto described.

CASE 2. J. McP., four years old, was struck by an automobile on August 8, 1950, and received multiple, serious injuries, including a fracture of the skull, multiple fractures of the pelvis with rupture of the urethra, and was unconscious for several days. His condition remained so precarious that no treatment was afforded the displaced right proximal tibial epiphysis other than immobilization in plaster. He was first seen by the authors six weeks after injury (Figs. 3-A and 3-B). At that time, there was a marked knock-knee deformity due to displacement of the proximal tibial epiphysis from an avulsion type of fracture (Type I) with anterior and medial displacement of the tibial shaft. Considerable callus formation prevented any attempt at closed reduction.

After consideration of the patient's age and our experience with similar displacements of epiphyses, it was felt that correction would occur in time provided that the epiphyseal plate had not been damaged. There was slight but definite abnormal motion present when the extended knee was abducted. The patient was allowed up on crutches without weight-bearing for another six weeks. At the end of this time, full active use of the leg was permitted.

The patient was seen and roentgenograms were made at regular intervals (Figs. 3-C and 3-D). When he was seen on January 1, 1951, five months after injury, the knock-knee deformity had disappeared clinically,

R FIG. 3-F L

L FIG. 3-G R

Figs. 3-F and 3-G. Anteroposterior and lateral roentgenograms made August 21, 1953, three years after injury. The valgus deformity has been completely corrected but a varus deformity is developing as a result of growth disturbance. Note the flattening of the medial portion of the tibial epiphysis.

but roentgenograms revealed that a slight deformity was still present (Fig. 3-E). The patient was last seen on August 31, 1953, three years after injury. There was no clinical deformity. The right knee showed 10 degrees of hyperextension and full flexion. There was a slight amount of abnormal lateral motion which seemed to have increased slightly in the past years. Roentgenograms (Figs. 3-F and 3-G) showed that the valgus deformity resulting from the original displacement was completely corrected. However, a varus deformity appears to be developing as a result of the growth disturbance which is unusual in a Type I fracture. The medial portion of the epiphysis appears to be flattened. The tibial shaft is longer on its lateral aspect, and the entire tibia is 0.6 centimeter shorter than the left. Should this deformity increase, which is highly probable, a serious problem will be presented as the child is now only seven years of age. Measures to prevent further deformity are indicated but the family has moved and cannot be located.

The mechanism of injury is similar in both of our cases, namely forced abduction of the leg on the knee. In both instances, the area of attachment of the tibial collateral ligament to the tibial epiphysis appears to have been larger than normal,—sufficiently large at least to maintain the tibial epiphysis in contact with the femoral condyles so that the tibial diaphysis was avulsed from under its epiphysis. In Case 1, the fracture line extended proximally through the lateral edge of the epiphysis. The ligamentous attachments to the epiphysis are not as large in most individuals, consequently forced abduction of the leg may cause rupture of the tibial collateral ligament, fracture of the proximal portion of both bones of the leg, lateral dislocation of the knee, or fracture of the distal femoral epiphysis or of the femoral shaft; but fracture of the proximal tibial epiphysis is rarely seen.

SUMMARY

Fracture of the proximal tibial epiphyseal cartilage is one of the most uncommon fractures of childhood. The immunity of this cartilage plate to injury is due to the absence of powerful ligamentous attachments to the periphery of the epiphysis. Most reported cases have resulted from hyperextension injuries and show posterior displacement of the tibial shaft with a high incidence of damage to the popliteal vessels. Two unusual cases are presented, both of which show an apparent anterior displacement of the shaft in relation to the epiphysis. In Case 1, the type of fracture has been reported only twice previously, while the medial displacement found in Case 2 has never been reported.

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Metaphyseal Fibrous Defects

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The purpose of this paper is threefold: (1) to summarize the known information regarding metaphyseal fibrous defects, (2) to establish their occurrence in the upper extremity, and (3) to propose a theory of their development and regression. Our observations are based on a review of the literature and on a series of seventeen lesions in fifteen patients. Only histologically verified lesions are included in this report, in spite of the fact that we see many metaphyseal fibrous defects that are not subjected to biopsy.

From time to time, asymptomatic cystic lesions are seen in the metaphyses of long bones of children and young adults. They are usually eccentrically located and are most often noted in the lower extremities. Microscopically they are found to be filled with fibrous tissue in a chaotic pattern interspersed with varying amounts of foam cells and multinucleated giant cells. The striking feature of these lesions, histologically, is that they show no evidence of new-bone formation (Figs. 1-A and 1-B).

In 1952, Phemister reported eleven cases of "a form of osteomyelitis pursuing a chronic course from the onset in which a circumscribed area of bone is broken down by fibroblastic activity and the space filled up with soft tissue . . . devoid of the usual microscopic changes of pyogenic infection." Since that time scattered reports of the lesions have appeared in the literature under various titles.

Among 101 healthy children whose knees were subjected to roentgenographic examination at yearly intervals, Sontag and Pyle found cystic lesions in the distal portion of

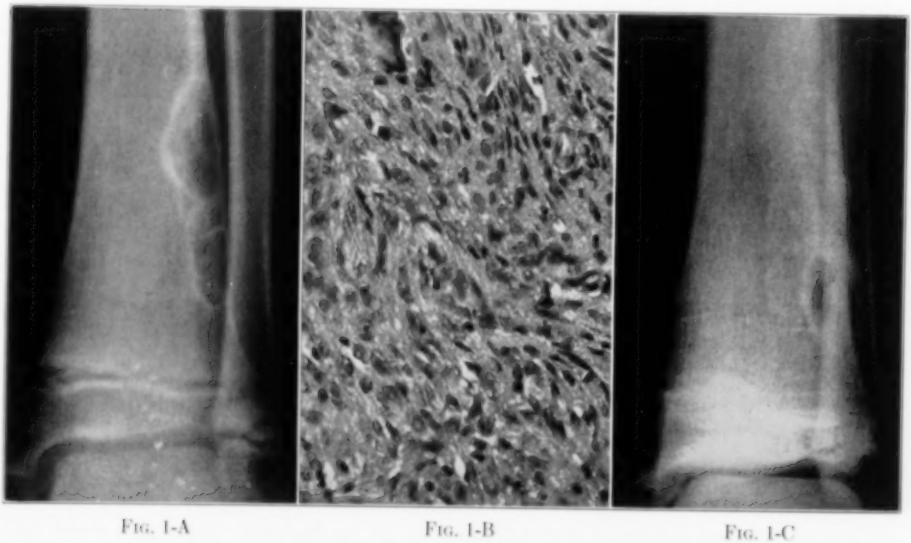

FIG. 1-A FIG. 1-B FIG. 1-C

Case 1. A typical metaphyseal fibrous defect.

Fig. 1-A: Note the eccentric location in the metaphysis of the distal portion of the tibia, the sharply defined periphery, and the orientation in the longitudinal axis.

Fig. 1-B: Whorls of well differentiated fibrous tissue showing an occasional multinucleated giant cell (× 230).

Fig. 1-C: A small remnant of the lesion persisting three years after curettage and bone-grafting.

TABLE I

	Jaffe and Lichtenstein	Hatcher	Cunningham and Ackerman
Upper Extremities			
Humerus, proximal			2
Radius, distal			1
Ulna, distal	1		
Lower Extremities			
Femur, proximal			1
Femur, distal	1	32	3
Tibia, proximal	3	11	1
Tibia, distal	1	5	7
Fibula, proximal	1		2
Fibula	2*		
Fibula, distal	1	2	
Site not stated		1	
Totals	10	51†	17

* End of bone not stated. † 17 cases histologically verified.

the femur in thirty-seven. As seen roentgenographically, these appeared to be metaphyseal fibrous defects; none, however, were subjected to biopsy for histological verification.

Caffee also discussed the lesion. His studies were based on a similar group of children whose hands and knees were subjected to roentgenographic examination at intervals. On none of the lesions was biopsy done.

Jaffe and Lichtenstein reported ten such lesions under the name *non-osteogenic fibroma of bone*. Hatcher reported a series of fifty-one lesions in forty-five patients. Histological verification of the biopsied material was done in seventeen instances. He coined the term *metaphyseal fibrous defect*. We prefer this latter term for several reasons: (1) the metaphyseal location of the lesion is clearly indicated and (2) the term *fibrous defect* indicates that the lesion is a developmental defect rather than a true neoplasm. This theory is supported by the case reported by Ponseti and Friedman in which three successive lesions arose from the same area of the epiphyseal plate. These were left behind in the metaphysis as bone growth in length took place and eventually became sclerotic about the periphery of the lesion and disappeared. This report suggests the final reason for preferring the term *metaphyseal fibrous defect*, for, in the course of spontaneous obliteration of the defect, new-bone formation may occur, and the term *non-osteogenic fibroma* would no longer be appropriate.

CLINICAL FEATURES

Age: The lesion is commonly found in children and, occasionally, in young adults. Fourteen of the fifteen patients in our series were between the ages of four and sixteen years; one patient was thirty-six years old at the time the lesion was discovered. This age incidence coincides well with that of the ten patients in Jaffe and Lichtenstein's series; in these the age range was from eight to sixteen years. In Hatcher's series, all but seven of forty-five patients were children at the time the lesion was recognized.

Sex: We found no sexual preponderance in our series; there were seven males and seven females. Jaffe and Lichtenstein also noted an equal distribution between the sexes. Hatcher's series included twenty-eight males and seventeen females; however, there was histological verification of the lesion in only seventeen of these.

Location: All of the lesions have been found in the metaphysis of the long bones of the extremities. The lower extremity is involved more frequently than the upper. Multiple

lesions were found in two of our patients. All of the fifty-one lesions in Hatcher's series were in the lower extremity. Our series includes fourteen lesions in the lower extremity and three in the upper extremity. In Table I the location of the lesions in our series and in the other two series is presented.

ROENTGENOGRAPHIC APPEARANCE

The majority of metaphyseal fibrous defects present a typical roentgenographic appearance. The lesions appear as well demarcated, radiolucent, uniloculated, and multiloculated cyst-like areas, eccentrically located in the metaphyses of the long bones of the extremities. They vary in size from about one centimeter in diameter to two by two by five centimeters and tend to have the greatest length in the long axis of the bone. The border varies from a hazy indistinct margin to a densely sclerotic, sharply defined periphery (Figs. 1-A, 2, and 4). The density of the margin apparently varies directly with the

FIG. 2

FIG. 3

Fig. 2: Case 2. An asymptomatic, poorly defined fibrous defect in the proximal metaphysis of the humerus.

Fig. 3: Case 8. Metaphyseal fibrous defects occurring in slender bones tend to occupy the entire width of the bone. Note the pathological fracture.

duration of the lesion, as indicated by the serial roentgenograms of the case of Ponseti and Friedman made during the development and regression of three lesions. The cortex is often bulged and thinned by the lesion, but it was found to be intact in most patients, except in those in whom a pathological fracture had occurred through the lesion. When the lesion occurs in a small bone such as the fibula (Fig. 3), it tends to occupy the entire width of the bone symmetrically. Only two lesions in our series were centrally located in a major long bone. One of these was a small lesion in the trochanteric region of the femur, and the other was a poorly defined lesion in the proximal metaphysis of the humerus (Fig. 2).

After pathological fracture through the defect, union often takes place in a normal period of time, but multiple small cystic lesions are left scattered about the site of the fracture (Figs. 6-A and 6-B).

FIG. 4-A FIG. 4-B

Case 4. The fibrous defect had eroded through the cortex of the femur.

CLINICAL MANIFESTATIONS

A metaphyseal fibrous defect usually causes no symptoms unless it is associated with a pathological fracture. Usually the lesion is discovered incidentally on examination of a neighboring part for some other complaint.

CASE 2. J.A., a four-year-old girl, sustained a fracture of the clavicle. Roentgenograms were made of the right humerus where a cystic area, one by one by two centimeters, was seen in the proximal metaphysis (Fig. 2). Three months later the lesion was curetted and the defect was filled with bone chips. The material removed was yellow-gray, fibro-fatty tissue which on histological examination proved to be a metaphyseal fibrous defect. At no time did she have symptoms referable to this defect.

It has been said that symptoms referable to a neighboring joint is a common manifestation of the defects. It should be pointed out, however, that, in most instances, there is an obvious cause for the symptoms other than the presence of the fibrous defect. For example:

CASE 1. J.H., a thirteen-year-old boy, had twisted his ankle nine months prior to admission to the hospital. Roentgenograms made at that time revealed an eccentrically placed cystic lesion in the distal tibial metaphysis (Fig. 1-A). Within a few days, the lesion became asymptomatic and remained so. Yellow, fibro-fatty material was curetted from the cystic area, and the defect was filled with iliac bone. The material removed had the histological characteristics of a metaphyseal fibrous defect (Fig. 1-B). Roentgenograms made four years later showed a small residual lesion (Fig. 1-C).

There have been several instances of alteration in the rate of longitudinal bone growth in our study.

CASE 4. F.S., a thirteen-year-old boy, had a fibrous defect one centimeter in diameter which was curetted from five centimeters above the epiphyseal plate on the medial aspect of the distal femoral metaphysis (Fig. 4). Overgrowth of this bone subsequently developed. However, at eighteen, the overgrowth amounted to only three-quarters of an inch. It appeared that nothing further would have to be done.

CASE 5. W.M., a ten-year-old boy, fell out of a tree and sustained a pathological fracture through a cystic area two by two by three centimeters in the distal portion of the tibia (Fig. 5-A). The limb was immobilized in a cast for six months and the fracture healed satisfactorily. The defect, however, remained. It was curetted

FIG. 5-A FIG. 5-B FIG. 5-C

Fig. 5-A: Case 5. This boy had sustained pathological fracture six months before this roentgenogram was made. There was solid fusion in spite of the persistence of the defect.

Fig. 5-B: A small cystic area persisted four months after curettage and bone-grafting.

Fig. 5-C: Two years after surgery. The small lesion had migrated (relatively) away from the epiphyseal plate. The remainder of the lesion was obliterated.

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 6. Note the multiple small cystic areas which remained after healing of a pathological fracture.

Fig. 6-B: The appearance following healing of a second pathological fracture sustained ten months later.

FIG. 7-A

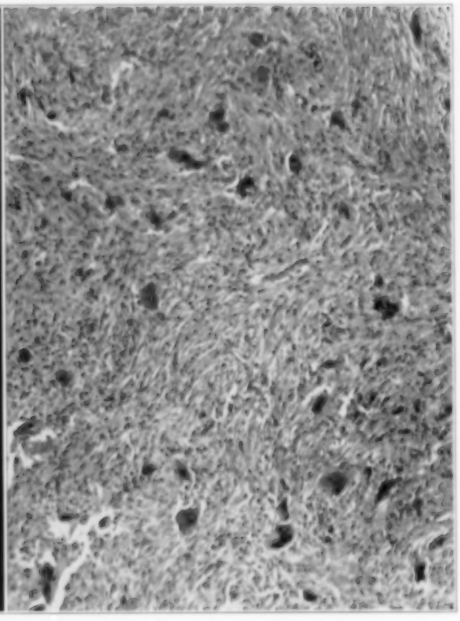

FIG. 7-B

Fig. 7-A: Case 7. A large fibrous defect that was curetted and filled with bone for prevention of pathological fracture.

Fig. 7-B: Note the chaotic whorls of fibrous tissue with large numbers of multinucleated giant cells (× 195).

and was found to be a metaphyseal fibrous defect. A small (one centimeter in diameter) defect (Fig. 5-B) remained in the area one year after surgery; this had almost disappeared by the third year after operation. A one-inch overgrowth of the tibia had occurred by the end of the second postoperative year and an epiphyseal arrest was done.

It should be noted that in Case 5 the stimulation of growth was possibly due to the operative intervention rather than to the presence of the lesion itself. If the lesion migrates away from the epiphysis, as Ponseti and Friedman have indicated, it would seem wise to delay any surgical procedure until the lesion is a safe distance from the epiphyseal plate. In the event that the findings in a particular case, considered in the light of the clinical history, present the possibility of malignant change, biopsy should, of course, be done without delay.

Pathological fractures through a metaphyseal fibrous defect usually heal satisfactorily; however, few of the lesions are obliterated by the healing process.

CASE 6. J.S., a sixteen-year-old boy, sustained two successive pathological fractures through a cystic area of the distal metaphysis of the right radius. Spontaneous healing occurred in each instance. After the fractures had healed, numerous cystic areas were noted about the fracture site (Figs. 6-A and 6-B). Curettage and bone-grafting were done with satisfactory results.

The problem of metaphyseal fibrous defects in regard to pathological fractures appears, therefore, to be purely structural in nature. Large lesions, involving a major portion of a bone, cannot be expected to undergo spontaneous obliteration after fracture because of the presence of a large amount of fibrous tissue.

CASE 7. D.L., a thirteen-year-old girl, had rheumatic fever at the age of twelve with associated bilateral ankle oedema. Some oedema persisted in the right ankle, and roentgenograms were made. These revealed a large lesion (Fig. 7-A) which was curetted; the defect was filled with bone in order to prevent pathological fracture.

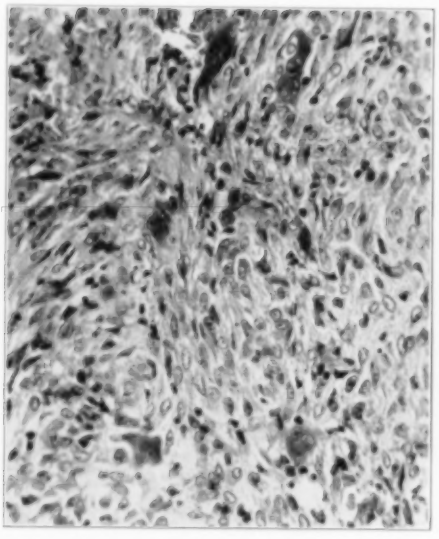

FIG. 8

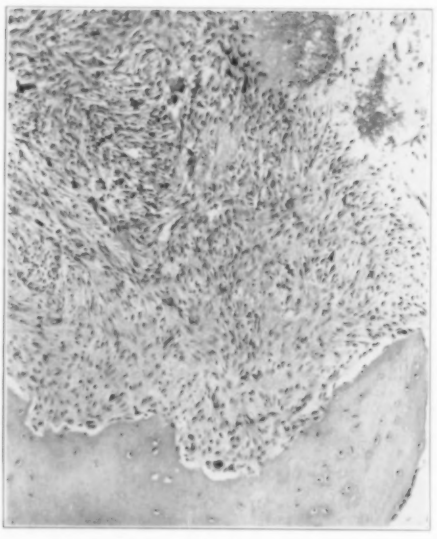

FIG. 9

Fig. 8: Case 5. Note the giant cells, in which the number of nuclei varies directly with the size of the cell, and the irregular pattern of the surrounding fibrous tissue (× 230).

Fig. 9: Case 9. Note the absorption of bone occurring at the periphery of this lesion, and the absence of any new-bone formation (× 83).

It seems reasonable that a large lesion should be curetted and that the defect should be filled with bone if it appears that pathological fracture may occur. If pathological fracture has occurred, union should be allowed to take place; the decision for surgical intervention should be made on the basis of the appearance of the defect after healing of the fracture.

The majority of metaphyseal fibrous defects are readily identifiable and need not be disturbed unless a biopsy is considered to be necessary.

Our experience is apparently similar to Hatcher's in that we see many lesions that are not subjected to biopsy because of the clarity of the clinical and roentgenographic picture. Twenty-two additional lesions have been diagnosed roentgenographically as metaphyseal fibrous defects at this Institution in the past two years; these have not been included in this study because the diagnosis was not verified histologically. Many other lesions have been seen in the private offices of the Attending Staff. Thus, the lesion is not uncommon.

PATHOLOGY

The defect presents a rather uniform gross and microscopic picture. The cortex of the bone is usually intact, and there is no thickening of the periosteum in patients without obvious pathological fracture. The lesion was found to have eroded through the cortex in only one of our patients (Case 4). The material removed from the majority of the defects was yellow-gray in color and had the consistency of soft fibro-fatty tissue. In a few instances, it was somewhat darker and more brown in color.

Microscopically, the lesion consists of very cellular fibrous tissue in a chaotic pattern of whorls and sheets of cells with varying numbers of multinucleated giant cells (Figs. 1-B, 7-B, and 8). The giant cells may have up to eight or ten nuclei, more or less evenly distributed in their cytoplasm. The size of the giant cells varies directly with the number of nuclei. Some lesions may show only an occasional giant cell (Fig. 1-B), while others

TABLE II

Case No.	Age Sex	Location of Lesion	Pathological Fracture	Treatment	History
1. J.H.	13 M	Tibia, distal	No	Curettage and bone-grafting	Twisted ankle 9 months prior to admission. X-rays showed cystic lesion in distal portion of the tibia. Lesion was asymptomatic soon after injury. X-rays, 2½ years after surgery, showed only a small defect which was asymptomatic.
2. J.A.	4 F	Humerus, proximal	No	Curettage and bone-grafting	Fractured clavicle 3 months prior to admission. X-rays revealed an asymptomatic lesion in the proximal portion of the humerus.
3. R.C.	11 F	Tibia, proximal	No	Curettage and bone-grafting	A cystic lesion was encountered in the proximal portion of the tibia during a patellar-tendon transplantation. This proved to be a metaphyseal fibrous defect. Review of earlier x-rays revealed that it had been present for 6 months, but was very difficult to see. No symptoms referable to the lesion were present 2 years later.
4. F.S.	13 M	Femur, distal	No	Curettage	Pain in the right knee for 1 month. X-rays revealed a small defect in the distal femoral metaphysis. Some overgrowth occurred in the femur over the next 4 years. This did not require treatment.
5. W.M.	10 M	Tibia, distal Femur, proximal	Yes No	Curettage and bone-grafting	Boy fell from a tree and sustained pathological fracture through a cystic lesion in the distal portion of the tibia. The fracture healed well, but multiple cystic areas remained and were curetted 8 months later. X-rays revealed a small lesion in the opposite femoral trochanter. There was overgrowth of one inch of the tibia by the second year postoperatively, necessitating epiphyseal arrest. The patient was well when last seen three years postoperatively.
6. J.S.	16 M	Radius, distal	Yes	Curettage and bone-grafting	Two successive pathological fractures of distal portion of the radius in 10 months, each healing but leaving multiple cystic areas. Two years after surgery there were no symptoms referable to the lesions, and no roentgenographic evidence of persistent defect.

7.	D.W.	13	F	Tibia, distal	No	Curettage and bone-grafting	Patient had rheumatic fever with bilateral ankle swelling. The swelling persisted about one ankle where x-rays revealed a large cystic lesion. This was operated upon for relief of symptoms possibly referable to it, and to prevent pathological fracture.
8.	D.D.	14	F	Fibula, proximal	Yes	Excision	Pathological fracture caused discovery of this lesion. Defect was asymptomatic over 10 years after excision.
9.	S.P.	15	F	Tibia, distal Fibula, proximal	No Yes	Curettage	Patient sustained a fracture above the lesion on the tibia, and through the fibular lesion after jumping from a low wall four months prior to admission. Lesion was asymptomatic at the time of biopsy.
10.	K.W.	16	M	Tibia, distal	No	Curettage and bone-grafting	Lesion discovered following fracture of tibia above the lesion.
11.	D.H.	36	F	Femur, distal	No	Curettage and bone-grafting	Patient had pain in knee after dancing. X-rays showed a defect in the supracondylar region.
12.	C.J.	7	F	Femur, distal	No	Curettage	Patient fell and injured her knee. X-rays revealed a five-by-two-centimeter supracondylar defect.
13.	M.R.	10	M	Tibia, distal	Yes	Curettage and bone-grafting	Patient sustained pathological fracture through defect in distal portion of the tibia when he kicked a soccer ball, two months prior to admission. The fracture healed well, but a cystic lesion remained and was curetted.
14.	V.O.	14	F	Humerus, proximal	Yes	Curettage and bone-grafting	Two pathological fractures of the humerus in 3 months. Both healed slowly. Elective curettage and bone-grafting was done.
15.	M.S.	12	M	Tibia, distal	No	Curettage and bone-grafting	X-rays in this patient with an osteochondroma of the femur revealed the tibial lesion.

may be heavily studded with them (Figs. 7-B and 8). Examination of the periphery of the lesion usually reveals finger-like projections of the fibrous tissue filling the intertrabecular spaces, with varying numbers of osteoclasts about the adjacent bone where resorption is in progress (Fig. 9). In some instances, the picture is more static, with fewer osteoclasts being noted; we have not seen evidence of peripheral new-bone formation. Occasionally small collections of foam cells are scattered throughout the fibrous tissue, but these do not constitute a major portion of the lesion. Resorption of bone about the periphery and the absence of new-bone formation within the fibrous tissue are constant findings. Occasional spicules of bone are seen within the lesion, but active bone resorption about the spicules is uniformly seen. Little or no mitotic activity is observed in the defect, and no metastases have been reported.

The histological appearance of the defect is usually distinctive enough for diagnosis. In the course of spontaneous obliteration of the defect, new-bone formation may occur; this has not been observed in any of our cases. This may be explained by the fact that most of the lesions are followed roentgenographically for a while, and are seldom subjected to biopsy if they are found to be diminishing in size.

Histologically the lesion differs from a bone cyst, with which it is most commonly confused clinically, in that the latter is either empty or contains loose fibro-fatty tissue in which foam cells predominate. This is in marked contrast to the more dense fibrous tissue with multinucleated giant cells seen in the fibrous defect.

The lesion should not be evaluated without roentgenographic examination, since the location of the lesion in the metaphysis is sufficient evidence to rule out giant-cell tumor of bone, with which the lesion may be confused, inasmuch as the giant-cell tumors occur only in the ends of the long bones, usually after ossification of the epiphyseal plate. Fibrous defects, seen after ossification of the epiphyseal plate, have usually migrated well away from the epiphyseal area.

We have seen three lesions diagnosed histologically elsewhere as giant-cell tumor of the metaphysis in children. Two of these were in the femur and the third was in the distal metaphysis of the radius. Because of the nature and the location of these lesions, we believe that all three were metaphyseal fibrous defects. An additional patient with a typical lesion was referred to us for diagnosis, no diagnosis being suggested by the pathologist submitting the case. There is no evidence that metaphyseal fibrous defects ever undergo malignant transformation.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of the lesion on the basis of the clinical and roentgenographic findings is not so serious a problem as it is in most bone lesions, inasmuch as the lesions with which they may be confused are, in the majority of instances, benign.

A metaphyseal fibrous defect is quite similar, as seen roentgenographically, to the lesion of monostotic fibrous dysplasia; both are commonly found in the younger age groups. In addition, both lesions are usually asymptomatic unless pathological fracture has occurred. Careful examination of the roentgenograms, however, will usually offer several clues in the differential diagnosis.

1. The metaphyseal fibrous defect is eccentrically located in the metaphyses (Figs. 1-A and 2), whereas the lesion of fibrous dysplasia is usually more centrally located.

2. The fibrous defect usually presents a more radiolucent appearance than does the lesion of fibrous dysplasia because of the fact that considerable new-bone formation is usually present in the latter.

3. Although peripheral ridging may give either of the lesions a multiloculated appearance, the metaphyseal fibrous defect usually presents at most two or three apparent loculations, whereas the lesion of fibrous dysplasia may have the so-called soap-bubble appearance often ascribed to giant-cell tumors of bone.

4. The long axis of the fibrous defect is usually oriented on the longitudinal axis of the bone (Figs. 1, 4, and 6-A).

5. The finding of generalized involvement as seen in polyostotic fibrous dysplasia is in marked contrast to the usually single or few metaphyseal fibrous defects found in any one patient.

Although metaphyseal fibrous defects have been found in persons in the third and fourth decade of life, they have by this age usually migrated a considerable distance from the ends of the bone and should, therefore, not be confused with giant-cell tumors which occur only in the ends of long bones.

Unicameral bone cysts may occasionally be confused with metaphyseal fibrous defects. Again, the eccentric position of the fibrous defects, their orientation in the long axis of the bone, and their predeliction for the lower extremities are of help in arriving at a diagnosis. In addition, fibrous defects in the early course of their development may have a poorly defined margin, whereas bone cysts are usually sharply outlined. It is not uncommon for a bone cyst to occupy the entire width of a major long bone, bulging and thinning its cortex over a wide area. Metaphyseal fibrous defects, on the other hand, rarely involve a major portion of a long bone except in the case of lesions occurring in the fibula (Fig. 3).

Other conditions such as osteomyelitis and tuberculosis may occasionally enter into the differential diagnosis. The clinical and laboratory findings will usually be of help in the diagnosis in these cases. When there is doubt, biopsy should be, of course, performed.

THEORY OF DEVELOPMENT AND REGRESSION OF METAPHYSEAL FIBROUS DEFECTS

Several facts indicate that the lesion arises as a result of some developmental aberration at the epiphyseal plate:

1. It has been found only in the metaphysis of a bone;

2. It migrates (relatively) away from the epiphysis as the bone grows in length;

3. It tends to be elongated in the longitudial axis of the bone, as though the abnormal development had occurred over a period of time;

4. Ponseti and Friedman have illustrated three successive lesions arising from the same area of the epiphyseal plate, indicating that the factors producing the defects may act intermittently;

5. No evidence of malignant transformation or unusual mitotic activity has been noted.

The more common occurrence of these lesions in the lower extremity would suggest that trauma might play some part in their origin, in that the lower extremities carry the body weight and are more frequently subjected to trauma during the growing period. The exact nature of the changes at the epiphyseal plate are unknown to us at this time.

Caffee believed that the cortical lesions arise from the periosteal surface and destroy bone from without in. He felt that the large, centrally located lesions are of different etiology and should be classed as non-osteogenic fibroma. We see no reason for postulating two different theories of origin for histologically identical lesions appearing at different locations in relation to the cortex. Some of the cortical lesions are larger than the centrally located ones. In addition, we have never seen these lesions increase significantly in size when they are away from the epiphyseal plate nor have we seen them disappear and reappear in the same location as some authors have mentioned. We believe these observations are based on variations in the positioning for roentgenograms.

The regression of the defect is equally difficult to evaluate. As stated previously, we have seen no evidence of new-bone formation in any of the lesions. One possible explanation of this is that most of the lesions are followed by serial roentgenograms and are not subjected to biopsy if they are found to be diminishing in size. Another possible explanation for their disappearance without new-bone formation is that they reach the surface

of the bone as the metaphysis is remodeled in the normal course of bone growth. The lesions that are more centrally located may escape the remodeling process and may thus persist in adult life at some distance from the epiphyseal plate. This distance, of course, would depend upon the age at which the defect occurred. If this theory is true, it follows that many of the shallow subperiosteal lesions diagnosed roentgenographically as subperiosteal desmoids [4] may be the remnants of metaphyseal fibrous defects being extruded from the bone by the process of remodeling.

The final solution of the problem of the development of these metaphyseal fibrous defects will undoubtedly be found in the course of unraveling the mysteries of growth at the epiphyseal plate.

SUMMARY

Metaphyseal fibrous defects are cystic lesions filled with fibrous tissue and are usually eccentrically located in the metaphyses of the long bones of the extremities of children and young adults. The lower extremities are most often involved. Histologically these defects are filled with whorls and sheets of fibrous tissue, varying numbers of multinucleated giant cells, and a few foam cells. The absence of new-bone formation is a constant finding. These lesions apparently arise as a result of some unknown process in which a small area of the epiphyseal plate intermittently produces fibrous tissue instead of bone. It would appear that many of these lesions may be extruded from the bone in the process of remodeling of the metaphysis during bone growth.

NOTE: We are grateful to Dr. Thomas G. Otto, Cape Girardeau, Missouri, for the history and roentgenograms of Case 1; and to the St. Louis Shriners' Hospital for Crippled Children for the histories of Cases 3, 5, and 7.

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The Influence of Splenectomy on the Induction of Osteogenic Sarcoma in Rabbits

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Osteogenic sarcoma may be induced in rabbits by the intravenous injection of zinc beryllium silicate[5, 6, 8]. In 1952 the authors undertook the experimental production of such tumors in order that they might have material on which they could test the therapeutic effectiveness of ultrasonic energy[12].

In this initial study it was found that when zinc beryllium silicate was given to normal rabbits, osteogenic sarcomata were produced in 50 per cent of the animals. These tumors arose in the medullary cavities of the long bones and extended through the cortices into the surrounding soft tissues. Metastases were found frequently in the lungs and less often in the liver. In these experiments the spleen appeared to play some role in tumorigenesis, for in all the animals in which tumors developed, there were atrophic changes within the spleen, whereas in those animals in which tumors did not develop after the administration of beryllium the spleens were functional and hyperplastic. Others have also noted changes in the spleens of rabbits in which bone tumors have been produced[6, 8].

The initial response in the spleens of these experimental rabbits following the injection of beryllium was an extensive phagocytosis of the beryllium by the histiocytes of the spleen in a manner similar to that described by Baillif in his study of colloidal thorium. Rapid degenerative changes then occurred in these histiocytes, leading to their destruction. This was followed by an apparent transformation of the reticuloendothelial components of the malpighian corpuscles into new functional histiocytes, which, in their turn, were destroyed by the beryllium which they attempted to isolate[7]. In this manner functional splenic tissue was slowly destroyed and this usually vascular cellular organ degenerated into an avascular fibrous remnant, hardly discernible in the splenic ligament. Bone tumors invariably developed in the rabbits in which splenic atrophy had occurred, whereas in the rabbits that remained tumor-free for months after the injections of beryllium the spleens were essentially normal.

During recent years a considerable volume of data has been assembled indicating that the spleen plays a role in protecting the organism against the lethal effects of ionizing radiations. It is known that total-body irradiation is a most important exogenous leukaemic agent in mice[13], and in recent experiments with mice it has been shown that when the spleen is removed the incidence of tumors following comparable exposures is increased[14] and that when the spleen is shielded during irradiation of the body, recovery is more rapid and survival time is prolonged[10]. In experiments by Jacobson the mere implantation of the spleen into the peritoneal space of irradiated animals demonstrated the protective role of the spleen[9, 11]. In other experiments in which C57 black mice were used, shielding of the spleen effectively decreased or prevented the induction of lymphoid tumors[15, 16].

In his review article of 1952, Jacobson[9] suggested for the first time that some humoral

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FIG. 1-A

Rabbit 1. Roentgenogram showing tumors of the lower part of the right femur, upper part of the right femur, upper part of the right tibia, right ilium, right ischium, and left ilium.

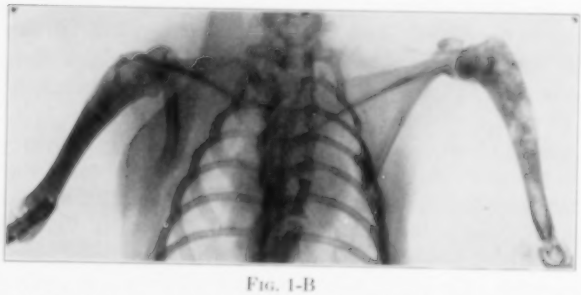

FIG. 1-B

Rabbit 1. Roentgenogram showing a tumor of the upper part of the left humerus. Note the obliteration of the medullary cavity of the right humerus.

factor or factors, produced by the cells of the spleen and perhaps by the cells of the bone marrow, might be instrumental in providing protection against radiation injury. In a study by Cole and associates [4] it was found that injections of homogenates of fresh normal spleen did provide protection. Further studies by Cole and associates on the protective factor in the spleen of mice [2, 3] indicated that this substance is unstable, heat labile, and radiosensitive and that it is associated with nuclear fraction of the splenic cells. They concluded that it is elaborated by the spleen and probably by the bone marrow but that it is not produced by the thymus, liver, muscles, or pulmonary tissue. Another recent study concerning the protective role of the spleen showed that extracts from the spleen contained a substance that neutralizes the effect of the plasma clot-retraction-time inhibitor which develops in dogs given lethal amounts of irradiation [17].

The data derived from these experiments seem to demonstrate that some humoral mechanism is elaborated by the spleen of mice and dogs. These findings support the authors' conviction that in beryllium-injected rabbits the loss of a functional spleen through atrophy may contribute in some way to the development of osteogenic sarcoma.

To test this hypothesis an experiment was planned in which splenectomies were to be performed before the rabbits received zinc beryllium silicate. It was felt that if a functional spleen does elaborate some substance that can inhibit the development of a bone tumor, then splenectomy should result in an increase in the incidence of tumorigenesis in rabbits injected with beryllium.

PROCEDURE

Eleven healthy white rabbits, weighing four to five kilograms each and free of obvious infection, were selected and isolated. Under pentobarbital sodium (nembutal) anaesthesia, splenectomy was performed with aseptic surgical technique. Recovery after operation was rapid and there were no obvious gross signs of deficiency as a result of the procedure in any of the animals.

After the rabbits had completely recovered from the operation, the same procedure which was described in a previous publication[12] was followed. Five milliliters of a 1 per cent suspension of zinc beryllium silicate were injected into an ear vein of each rabbit

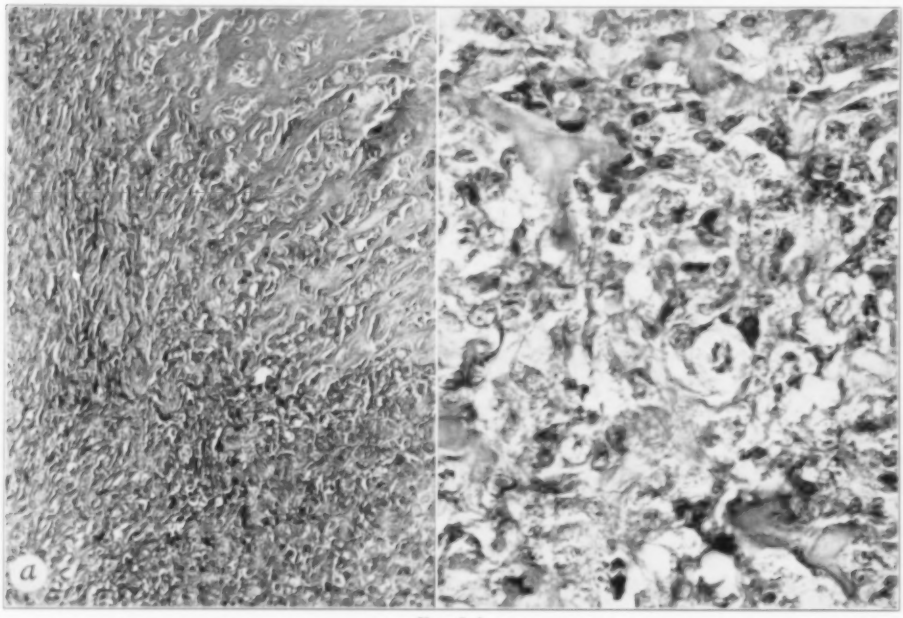

FIG. 2-A

Rabbit 1. Photomicrographs of the upper part of the right tibia showing an anaplastic osteogenic sarcoma in which osteoid has been produced. (Hematoxylin and eosin, × 100 and × 450.)

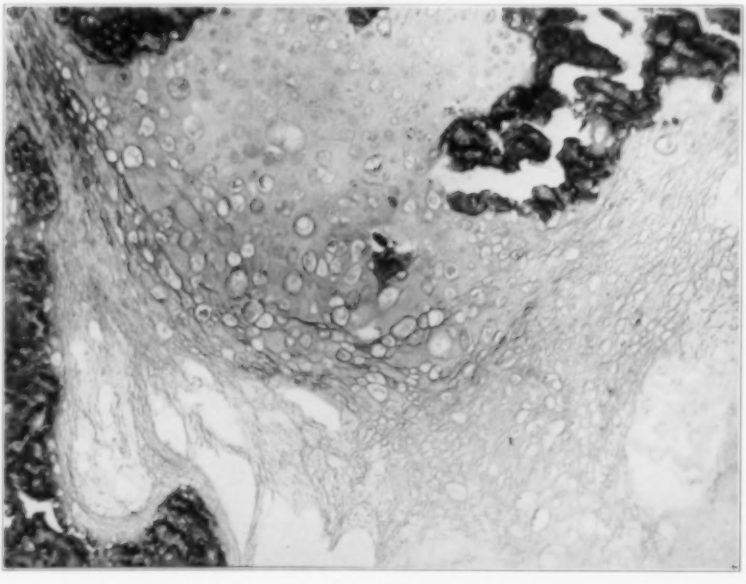

FIG. 2-B

Rabbit 2. Photomicrograph of upper end of the left humerus showing chondroblastic osteogenic sarcoma in which there are highly anaplastic cells. (Hematoxylin and eosin, × 95.)

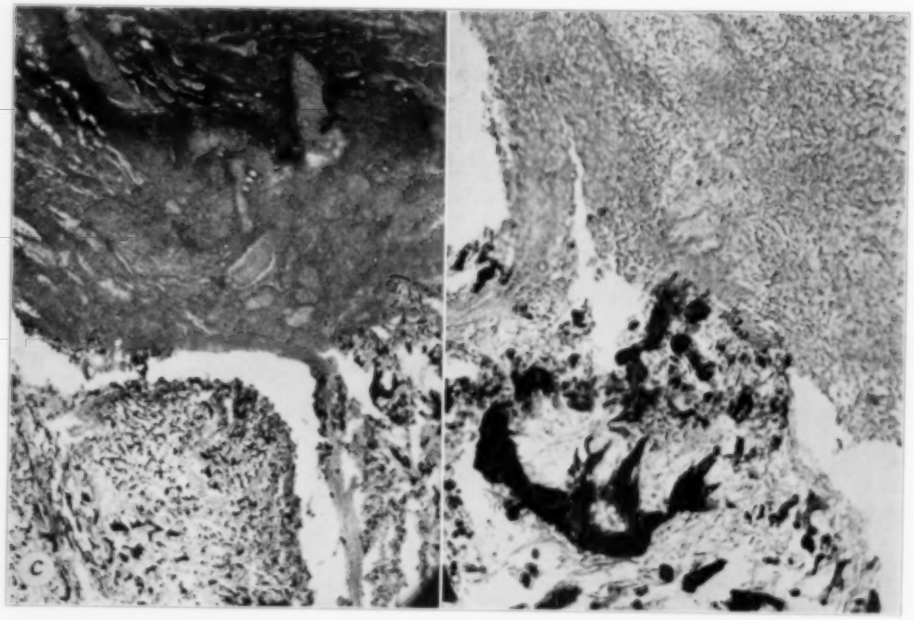

FIG. 2-C

Rabbit 3. Photomicrographs of left ischium showing osteogenic sarcoma with extensive necrosis. (Hematoxylin and eosin, × 100 and × 400.)

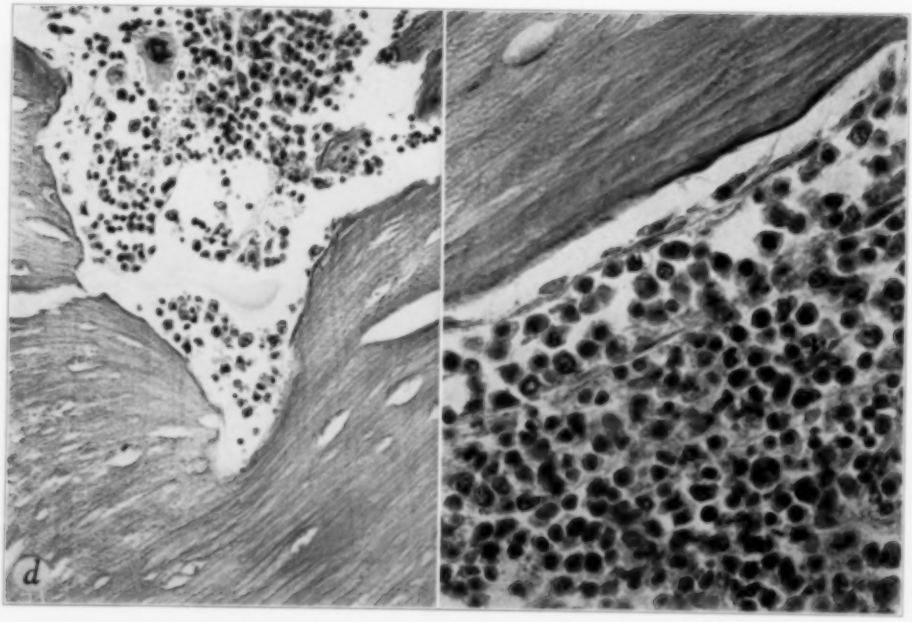

FIG. 2-D

Rabbit 4. Photomicrographs of the medullary cavity of the left femur. The bone shown in these sections is not the normal cortex of the femur but is new bone formed within the medullary cavity. Hematopoietic elements are present. (Hematoxylin and eosin, × 265 and × 525.)

twice a week for ten weeks. At the end of this time each animal had received the equivalent of one gram of beryllium. All the necessary precautions concerning the use of this substance, as previously noted[12], were observed. The animals were housed individually and moist litter was kept under them at all times, in order that the beryllium which was slowly eliminated through the kidneys would not be volatilized and thus prove hazardous to the caretakers.

RESULTS

Of the eleven rabbits that received injections, three died, of causes unrelated to the experiment, before the length of time required for the earliest bone changes to appear had elapsed[12]. In seven of the eight survivors, osteogenic sarcoma developed. The other animal died as a result of a respiratory infection nine months after the last injection of beryllium. This animal showed partial obliteration of the medullary cavities of the long bones, a condition which the authors have found to be a forerunner of beryllium-induced osteogenic sarcoma in rabbits.

The following is a summary of the protocols of the eight rabbits.

FIG. 3

Rabbit 5. Roentgenogram showing osteoblastic tumors of both ilia.

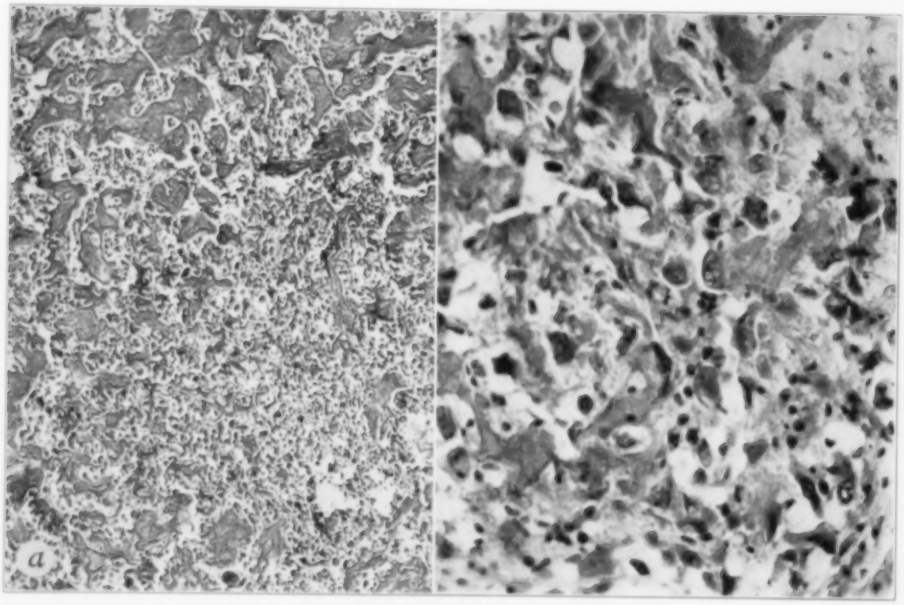

FIG. 4-A

Rabbit 5. Photomicrographs of left ilium showing osteogenic sarcoma. (Hematoxylin and eosin, × 100 and × 385.)

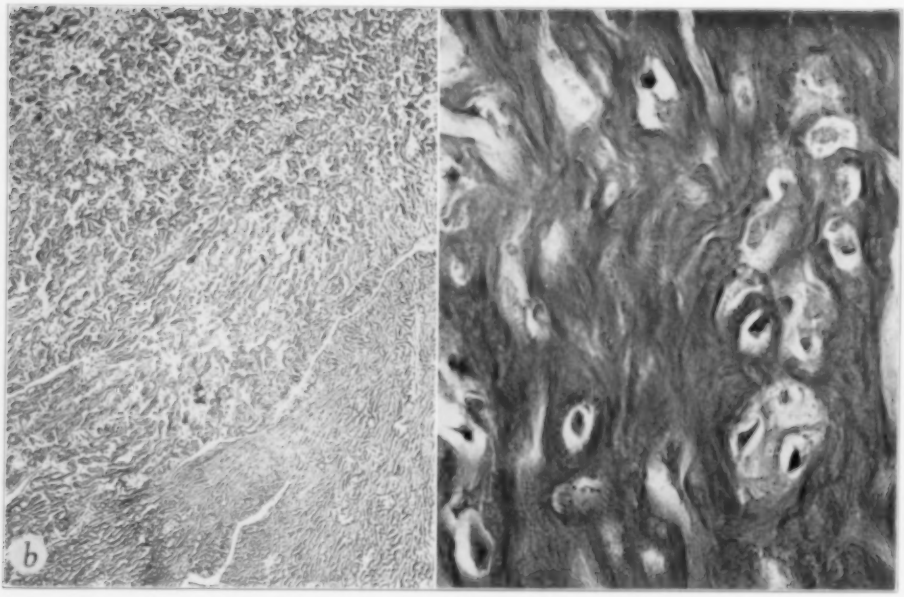

FIG. 4-B

Fig. 4-B: Rabbit 6. Photomicrographs of left ischium showing sclerotic osteogenic sarcoma. (Hematoxylin and eosin, × 36 and × 400.)

FIG. 5

Fig. 5: Rabbit 7. Photograph of gross specimen showing a large tumor in the lower end of the left femur.

Rabbit 1: This animal was sacrificed eleven months after the last injection of beryllium. Grossly, tumors were noted in the following locations: upper part of the left humerus, upper part of the right femur, lower part of the right femur, upper part of the right tibia, upper part of the left tibia, right ilium, left ilium, and right ischium (Figs. 1-A and 1-B). A microscopic section from the tumor in the upper part of the right tibia showed an anaplastic osteogenic sarcoma producing osteoid (Fig. 2-A).

Rabbit 2: This animal died ten months after the last injection of beryllium. There was complete obliteration of the medullary cavity in the right femur. In the lungs there was gross and microscopic evidence of metastatic lesions. A large tumor was observed at the upper end of the left humerus, and microscopic examination of this tumor revealed that it was a chondroblastic osteogenic sarcoma with highly anaplastic areas (Fig. 2-B).

Rabbit 3: This animal died ten months after the last injection of beryllium. It had an obvious infection in the upper part of the respiratory tract, but it was in a good state of nutrition. In the lungs there was gross and microscopic evidence of metastatic osteogenic sarcoma. The left ischium was the site of a tumor which, on microscopic examination, was found to be an osteogenic sarcoma with extensive necrosis (Fig. 2-C).

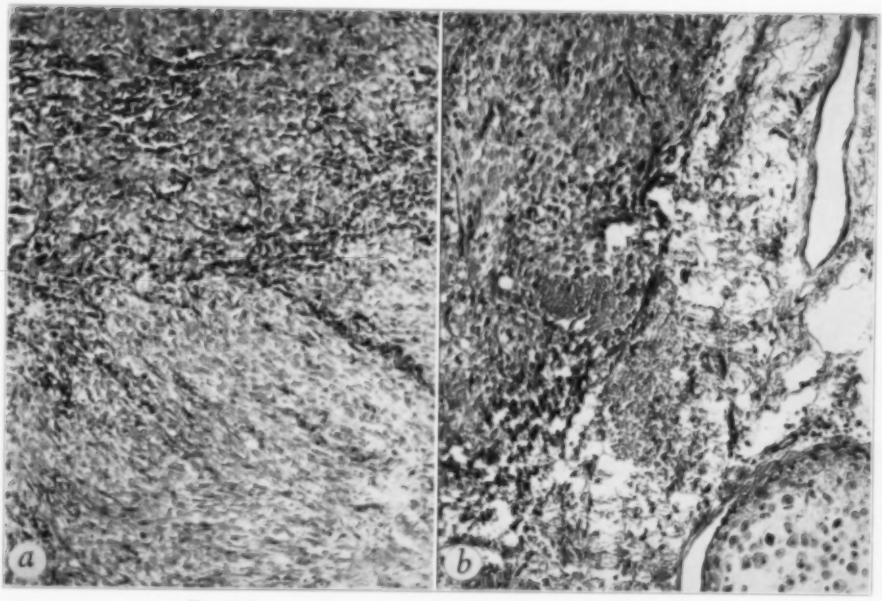

FIG. 6-A FIG. 6-B

Fig. 6-A: Rabbit 7. Photomicrograph of the lower end of the left femur showing anaplastic osteogenic sarcoma. (Hematoxylin and eosin, × 100.)

Fig. 6-B: Rabbit 8. Photomicrograph of the upper end of the left humerus showing chondroblastic osteogenic sarcoma. (Hematoxylin and eosin, × 120.)

Rabbit 4: This animal died nine months after the final injection of beryllium. There were multiple abscesses in the lungs, as well as a large abscess in the region from which the spleen had been removed. Grossly, no tumors were noted, but roentgenograms showed partial obliteration of the medullary cavities of the long bones. A microscopic section of the left femur (Fig. 2-D) showed that the medullary cavity had been replaced by new bone, although in a space within this new bone hematopoietic elements were present. The authors believe that this is the earliest stage in the development of osteogenic sarcoma in rabbits following injections of beryllium. Had this animal lived longer, a tumor would have developed, according to the authors' previous observations[12].

Rabbit 5: This animal died nine months after the last injection of beryllium. It was well nourished but had had paralysis of the hind legs for one month prior to death. Grossly, the lungs were seen to be involved with metastatic lesions, and microscopic sections of the lungs showed typical metastatic osteogenic sarcoma. Large tumors were present in both ilia (Figs. 3 and 4-A).

Rabbit 6: In this animal a respiratory infection developed eight months after the last injection of beryllium; the animal was therefore killed. A tumor had developed in the left ischium (Fig. 4-B), and metastatic nodules were present in the lungs and liver. In the lungs, the lymphatic radicles were distended with sarcoma cells which had infiltrated into the adjacent alveolar spaces and had formed osteoid tissue. In the liver, metastatic nodules were found in which there were many mitotic figures, osteoid tissue, and irregular formations of bone. Calcium had been laid down in plaques or sheets within these nodules.

Rabbit 7: This animal was sacrificed eleven months after the final injection of beryllium. Metastatic lesions were present in the lungs. A large tumor was found at the lower end of the left femur (Fig. 5). This animal also had tumors in the upper part of the right humerus, in the lower part of the left femur, and in the right ischium. There were pathological fractures through the tumors in the right humerus and left femur. A microscopic

section of the tumor in the left femur showed that it was an anaplastic osteogenic sarcoma (Fig. 6-A).

Rabbit 8: This animal was sacrificed eleven months after the final injection of beryllium. At this time it was well nourished. There were metastatic lesions in the lungs. A large chondroblastic osteogenic sarcoma was found in the upper end of the left humerus (Fig. 6-B).

SUMMARY

Following splenectomy, eleven healthy rabbits were given zinc beryllium silicate. Three animals died before sufficient time had elapsed for the production of osteogenic sarcoma. In seven of the remaining eight animals, osteogenic sarcoma developed, while in the eighth new-bone formation was found in the medullary cavity of the long bones at the time of death. This condition the authors have come to recognize as the forerunner of beryllium-induced osteogenic sarcoma in rabbits. The incidence of tumor in these rabbits (100 per cent) is definitely higher than the incidence in rabbits in which splenectomy was not performed prior to the injection of beryllium (50 per cent)[12].

Obviously, further study of a larger number of splenectomized rabbits to which beryllium has been given will be necessary before it can be stated conclusively that the presence of the spleen in a rabbit provides protection against the development of beryllium-induced osteogenic sarcoma. Nevertheless, the results of the present study do suggest that this is the case.

NOTE: The authors are grateful to Dr. D. C. Dahlin, Consultant in Surgical Pathology of the Mayo Clinic, for his continuing interest, for his aid in the preparation of stained sections of material, and for his interpretation of the pathological processes.

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Benign Chondroblastoma *

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Benign chondroblastoma has become firmly established as a distinct entity among the primary tumors of bone. The proliferating cells of this neoplasm produce foci of chondroid matrix, and this attribute is the rationale for classifying it as a neoplasm of cartilaginous derivation. Prior to the work of Jaffe and Lichtenstein [13], benign chondroblastoma was commonly grouped with the giant-cell tumors, often as a variant.

The first detailed description of chondroblastoma is generally credited to Codman, in 1931. Actually, however, it was Ewing who first called attention to this tumor, in the *Report of the International Conference on Cancer* in 1928. He described the lesion as a "calcifying" giant-cell tumor, considering it to be a variant of this type of tumor. Codman, in 1931, while working with the Bone Tumor Registry, found nine examples of this tumor, all of which had occurred in the upper end of the humerus. This location fell within his own special field of interest, the shoulder. He described these lesions and called them "epiphyseal chondromatous giant-cell tumors". Subsequently this neoplasm became known as "Codman's tumor" and was for a time thought to occur only in the upper end of the humerus.

In 1942, Jaffe and Lichtenstein [13] described the tumor in detail. They designated it as a separate and distinct entity, having no relationship to giant-cell tumor, and they renamed it "benign chondroblastoma of bone". Their study of nine cases convinced them that it was basically cartilaginous. In seven additional publications [5, 6, 8, 9, 12, 19, 23] thirty-four of these neoplasms have been reported and the original concepts have been corroborated. In 1949, Copeland and Geschickter published a survey of twenty-five cases. In this series there were fifteen tumors that they considered malignant. The existence of a malignant form of chondroblastoma has not been corroborated, however, and is even denied by Lichtenstein [18]. Valls, Ottolenghi, and Schajowicz, in 1951, proposed that this tumor had a reticulohistiocytic origin. Their evidence for this hypothesis was derived from the use of a silver staining technique in eight cases. The few remaining references to this lesion in the literature are, for the most part, concerned with differential diagnosis. In some publications [15, 20] the lesion has been erroneously classified.

MATERIALS

Sixteen examples of benign chondroblastoma of bone were found as the result of a thorough review of all the cases of bone tumor listed in the files of the Mayo Clinic. The clinical records of all of the patients in whom these lesions occurred were reviewed. In fourteen of the cases formalin-fixed gross specimens were available for study, and several sections from each tumor, stained with hematoxylin and eosin, were examined. Roentgenograms or photographs of roentgenograms were available in fifteen of the cases.

* Abridgment of the thesis submitted by Dr. Kunkel to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

† The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

TABLE I

CLINICAL FINDINGS IN SIXTEEN CASES OF CHONDROBLASTOMA

Case No.	Age (Years)	Sex	Site	Treatment	Follow-Up
1	8	M	Lower femur	Curettage and roentgen therapy	Recurred after 9 years
			Recurrence	Excision	Well 14 years later
2	44	M	Innominate (ilium)	Curettage	Well 12 years later
3	18	M	Upper humerus	Resection and bone-grafting	Well 6 years later
4	54	F	Innominate (acetabulum)	Amputation	Well 8 years later
5	16	F	Lower femur	Curettage and bone-grafting	Well 3 years later
6	10	M	Lower femur	Amputation	None
7	15	M	Upper femur	Curettage and roentgen therapy	Well 11 years later
8	14	F	Scapula	Curettage and roentgen therapy	Well 21 years later
9	18	F	Upper humerus	Curettage and roentgen therapy	Well 18 years later
10	19	F	Lower femur	Curettage and roentgen therapy	Well 3 years later
11	18	F	Upper femur	Curettage and roentgen therapy	Well 18 years later
12	21	M	Upper humerus	Curettage and cautery	Well 12 years later
13	21	M	Innominate (ilium)	Biopsy and roentgen therapy	Well 5 years later
14	31	M	Scapula	Biopsy and roentgen therapy	Well 12 years later
15	18	M	Upper femur	Curettage and bone-grafting	Well 3 years later
16	51	M	Innominate (ischium)	Biopsy	Well 3 years later

CLINICAL FINDINGS

Incidence: Chondroblastoma is a rare tumor. The sixteen patients in whom this tumor was found constituted less than 1 per cent of the total number of patients listed in the files of the Mayo Clinic as having primary tumors of bone.

Age and sex: One patient in this series was eight years old, one was ten years old, ten were from fourteen to twenty-one years old, and the remaining four patients were between thirty-one and fifty-four years old (Table I). There were ten males and six females.

Anatomical distribution (Table II): Ten of the sixteen tumors in this series occurred in the long tubular bones, seven being in the femur and three in the humerus. Four of the other tumors involved the innominate bone, two arising in the ilium, one in the ischium, and one in the acetabulum. The two remaining tumors occurred in the scapula, one involving the entire body and the other abutting on the glenoid cavity.

Nine of the ten tumors which occurred in the long bones were entirely or partially in the epiphysis, although one of them (Case 6, Table I) was predominantly metaphyseal. The tenth was in the metaphysis but abutted on the epiphyseal plate (Case 1, Table I). The location of the other six tumors was such that all could have been associated with secondary centers of ossification.

Signs and symptoms: In fifteen of the patients the presenting complaint was local pain, and in the sixteenth patient it was swelling. The duration of symptoms varied from three months to sixteen years, the average duration being slightly more than two years. The complaints concerned the adjacent joint in most cases. Other features which were noted were instability or limitation of motion of the adjacent joint or both, stiffness, weakness of the affected limb, limping, and swelling. Except in one case the general health of the patient was good, and in all instances the laboratory findings disclosed no significant abnormalities.

Physical examination: There was a palpable mass in the area of the tumor in seven instances, and limping and muscle wasting were common findings. Unusual features

TABLE II

ANATOMICAL LOCATION OF CHONDROBLASTOMATA

Location	No. of Cases in this Series	No. of Cases Reported in Literature*	Total No. of Cases
Femur			
Upper	3	3	6
Lower	4	11	15
Not localized	0	3	3
Humerus			
Upper	3	11	14
Not localized	0	2	2
Tibia			
Upper	0	7	7
Lower	0	2	2
Innominate bone	4	0	4
Radius	0	1	1
Scapula	2	0	2
Talus	0	2	2
Metacarpal	0	1	1
Total	16	43	59

* References 3, 6, 8, 9, 12, 14, 16, 23. The nine cases reported by Codman have been omitted because they were selected cases, chosen on the basis of Codman's special interest in the shoulder.

included swelling of the joint and dilation of the veins overlying the tumor. There was a significant loss of weight in only one case. No pathological fractures had occurred.

ROENTGENOGRAPHIC FINDINGS

The roentgenographic appearance of the tumors in the long bones in this series was in accord with the descriptions of chondroblastoma given by Pugh, by Coley and Higinbotham, and by others [10]. The lesion tends to be round or ovoid in contour. It may be confined to a part of an epiphysis, if small; or it may extend through the epiphyseal plate into the metaphysis and diaphysis, if large (Figs. 1-A and 1-B). Lesions which extend into the metaphysis may grow so large that the overlying cortex is expanded and sometimes is even destroyed.

In the authors' series the smallest lesion was about one centimeter in diameter, while the largest was so big that it destroyed most of the scapula. Regardless of the size of the tumor, its roentgenographic appearance was usually that of a fuzzy, mottled, rarefied focus. Frequently there was a fairly well defined, narrow, encircling line of sclerosing bone around the tumor. The tumors which occurred in the pelvis and scapula in this series were quite variable in their roentgenographic appearance. Two of those occurring in the pelvis appeared to be malignant.

The most important diagnostic information provided by the roentgenogram is the exact location of the lesion.

GROSS PATHOLOGY

Gross pathological material was available for review in all the cases but two; in seven cases the specimens that were available were practically complete. The lesions varied in size, the largest being seven by five by five centimeters and the smallest being one centimeter in diameter. In some instances the tumor was surrounded by a thin zone of sclerotic bone. For the most part the lesions were composed of a dark blue-gray substance which was either friable or somewhat rubbery. Only rarely was this material

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 3. Chondroblastoma in the epiphysis of the upper three centimeters of the humerus. The tumor has spread across the epiphyseal line. Its fuzzy rarefied appearance is typical. Periosteal reaction is present, and the lesion involves the articular cartilage.

Fig. 1-B: Case 3. Note the somewhat variegated appearance of the lesion, which has broken through the articular cartilage.

predominantly cartilaginous. In some lesions there were cystic changes, necrosis, and hemorrhage, which gave the gross specimen a variegated appearance. The tumors tended to be round or ovoid in shape, with poorly lobulated surfaces. Calcification and bone formation within the tumor substance were not noticeable features. There were no diagnostic features found in the gross appearance of these tumors except that they did not appear to be aggressive.

HISTOPATHOLOGY

The basic proliferating cell of these tumors is considered to be a chondroblast. It is an ovoid cell of medium size, with a roundish or oval nucleus which is often indented (Figs. 1-C, 1-D, and 2). Its cytoplasm is slightly acidophilic and the cell borders are ordinarily clearly defined. There is little interstitial substance in the cellular areas of these tumors. In every tumor "chondroblasts" with mitotic figures are found, but they are never frequent (less than one per five high-power fields).

Intermingled with the neoplastic cells are variable numbers of benign multi-nucleated giant cells (Figs. 1-C and 1-D). These cells ordinarily contain from five to forty nuclei, but in most of the tumors in the authors' series occasional cells containing more than fifty nuclei were also found. In general the giant cells in a chondroblastoma are somewhat smaller and less abundant than those in a giant-cell tumor of bone. The nuclei of these cells may resemble closely those of the "chondroblasts" of the cellular areas of the tumors. Areas of hemorrhage, necrosis, or microscopic-sized cysts may be present.

Distinctive zones of a chondroid material are found in all chondroblastomata. These zones may be relatively rare, occurring only in parts of the tumor, but usually they are numerous and in two cases in the authors' series they were even more prominent than the cellular areas. The poorly formed chondroid substance has been aptly likened to the ground substance which is found in mixed tumors of a salivary gland. In what

Fig. 2: Case 16. Chondroblastoma of the ischium. This photomicrograph shows a sheet of characteristic stromal cells (hematoxylin and eosin; × 200).

Fig. 3: Case 8. Typical chondroblastoma which occurred in the scapula. Note the characteristic zones of calcifying chondroid material (hematoxylin and eosin; × 100).

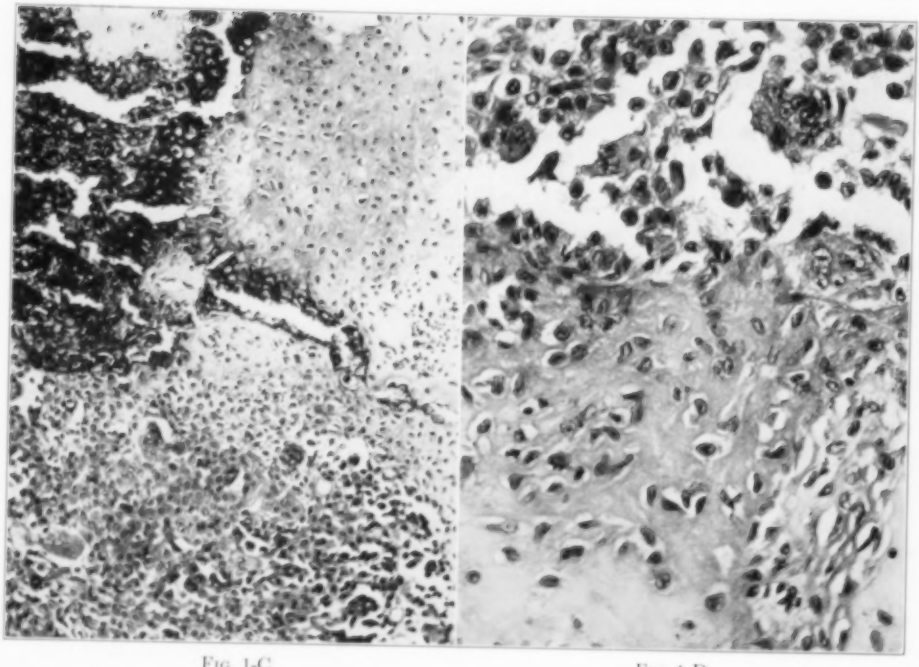

FIG. 1-C FIG. 1-D

Fig. 1-C: Photomicrograph of the lesion shown in Figures 1-A and 1-B. Typical giant cells and stromal cells can be seen below and chondroid matrix can be seen above. The matrix is becoming calcified, as may be seen in the left upper corner (hematoxylin and eosin; × 130).

Fig. 1-D: Higher magnification of lesion shown in Figure 1-C illustrating cell detail (hematoxylin and eosin; × 285).

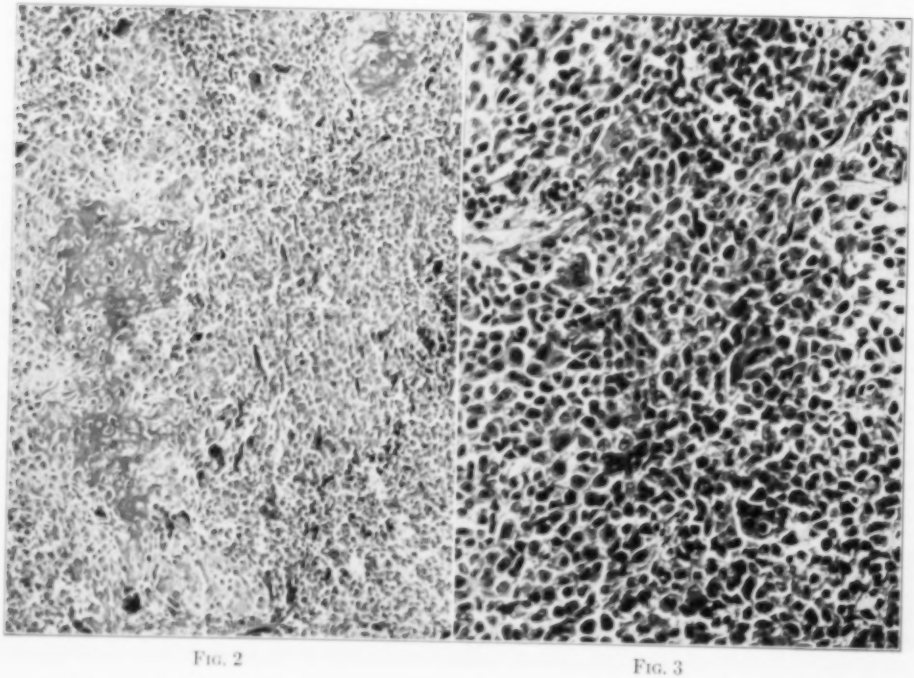

FIG. 2 FIG. 3

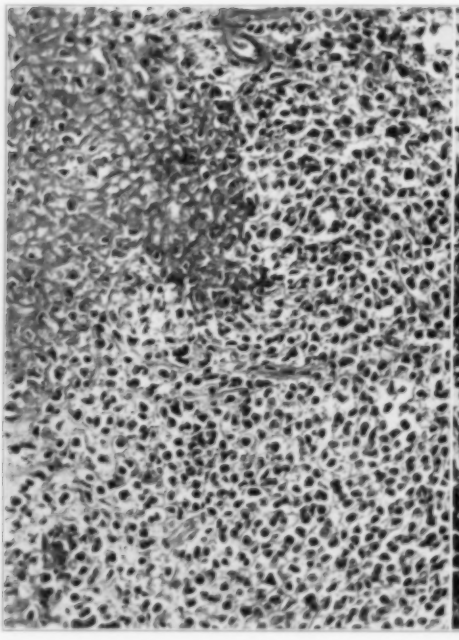

FIG. 4

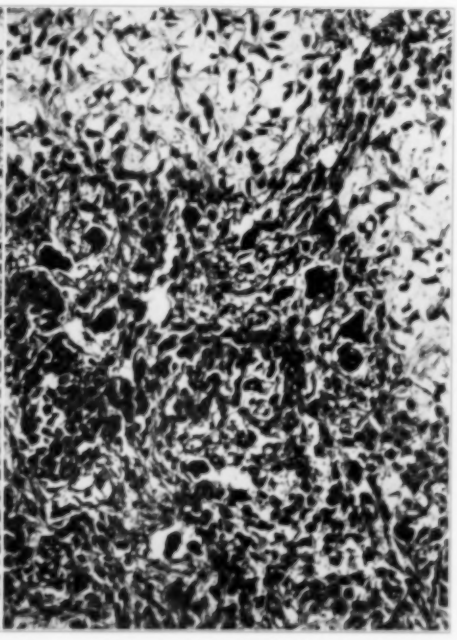

FIG. 5-A

Fig. 4: Case 4. Chondroblastoma of the acetabulum. In addition to a large zone of chondroid material, there are thin strands of material of similar staining quality which surround the individual cells (hematoxylin and eosin; × 145).

Fig. 5-A: Case 1. Photomicrograph of tissue from the original chondroblastoma showing prominent zones of tissue typical of chondromyxoid fibroma. Two of these zones appear at the top (hematoxylin and eosin; × 165).

are apparently older portions of the tumor this matrix may become calcified (Figs. 1-C and 3), a characteristically lace-like pattern, in which the cells are no longer visible, being produced (Fig. 4). In the two patients mentioned previously the chondroid material bore a striking resemblance to true hyaline cartilage. One of these patients (Case 14) now has a large area of calcification in his scapula. About 50 per cent of the original lesion in this patient was composed of fields of "chondroblasts", with occasional benign giant cells. In some of the patients part of the chondroid substance was disposed in thin strands between which there were normal-looking stromal cells (Fig. 4).

Two of the patients in this series furnished convincing histological evidence that benign chondroblastomata are closely related to chondromyxoid fibromata of bone. The lesions in both these patients contained equally prominent zones of chondroblastoma and chondromyxoid fibroma. One of these patients (Case 1) originally had a chondroblastoma (Fig. 5-A), but the tumor that recurred nine years after curettage was a typical chondromyxoid fibroma (Fig. 5-B). This tumor was excised locally and fourteen years later had not recurred. These two patients were the youngest in the series, being eight and ten years old, respectively. In both the bulk of the tumor was in the lower metaphysis of a femur; in one the epiphyseal plate and epiphysis were definitely involved as well, but in the other the tumor seemed to be limited by the epiphyseal line, and the epiphysis was not involved.

Further evidence of the relationship of chondroblastoma and chondromyxoid fibroma has been provided by Dahlin. He studied three patients with lesions which he classified as chondromyxoid fibroma. Two of these lesions were predominantly chondromyxoid fibroma in type but, as was evident in the numerous fields examined, they also

Fig. 5-B: Case 1. Section from the tumor which recurred nine years later. Only chondromyxoid fibroma tissue was found in this tumor, and there were no areas of chondroblastoma tissue (hematoxylin and eosin; × 80).

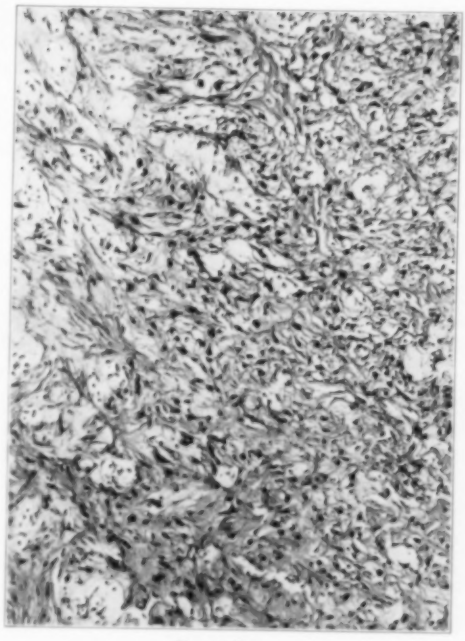

Fig. 5-B

contained cells which were typical of chondroblastoma, these cells making up 10 to 20 per cent of the tumor. Furthermore, cells were found which represented transitions between the chondroblasts of the cellular zones and the cells of the chondromyxoid fibroma. In the third case, the tumor appeared to be a "pure" chondromyxoid fibroma, but when it recurred twenty months after curettage, it contained small foci that were characteristic of benign chondroblastoma. It should be emphasized that these chondroblastomatous areas were not simply cellular interlobular zones containing a few giant cells but were areas which contained clusters of the type of basic proliferating cell which is observed in the pure chondroblastoma.

TREATMENT AND RESULTS

A summary of the data is given in Table I. Removal of the tumor by curettage or excision was performed in ten of the patients and in six of these patients supplementary roentgen therapy was also employed. In one patient in the latter group the tumor recurred nine years after the first treatment; there has been no recurrence since the second excision, however. Two patients were treated by partial removal and roentgen therapy. These patients have remained well for five and twelve years respectively, although in the latter (Case 14) a palpable mass is still present in the region of the scapula. Of the two patients treated by amputation one (Case 4) was well eight years later but the other (Case 6) could not be traced. The latter patient was treated in 1916, at which time giant-cell tumors were generally considered to be malignant and it was not known that there were variants of this type of tumor, such as the chondroblastoma. Resection of the upper end of the humerus resulted in a cure in one case. One patient with a typical lesion in the ischium has lived three years following treatment by biopsy alone. At present this patient has no symptoms referable to the tumor.

As late as 1953, overdiagnosing benign chondroblastoma was apparently still a rather common error, as was evidenced by a series of diagnoses submitted to the 1953 Seminar of the American Society of Clinical Pathologists [21]. Thirty-five per cent of the pathologists said that the chondroblastoma which was shown to them on a slide was a malignant tumor, whereas only 38 per cent arrived at the correct diagnosis. Caution should be recommended to the orthopaedist who believes that all central cartilaginous tumors of the pelvic and shoulder girdles must be treated by radical operations. The benign chondromyxoid fibroma, as well as the benign chondroblastoma, can occur in these locations.

DISCUSSION

In the cases of chondroblastoma reported in the literature the age of the patients is almost exclusively between ten and twenty-five years. In the authors' series, however, the age span was from eight to fifty-four years. As was mentioned previously, the two

youngest patients had somewhat atypical lesions. Excluding these two patients, then, the age range was from fourteen to fifty-four years. The male-to-female ratio of ten to six in these cases was less than the four-to-one ratio in the previously reported cases.

The fact that four tumors involved the innominate bones and two were in the scapula is noteworthy, since no report of benign chondroblastoma occurring in these sites was found in the literature. The presence of chondroblastoma in the flat bones is not inconsistent with the hypothesis that this tumor is of epiphyseal origin, for the innominate bones and the scapula both have multiple primary centers of ossification.

As can be seen in Table II, the locations of the remainder of the tumors were similar to those of the tumors in the other reported cases. There were seven lesions in the femur and only three in the humerus. None of the patients in this series had multiple tumors, and none with multiple tumors have been reported in the literature.

The onset of symptoms from chondroblastoma is usually insidious. By far the commonest complaint is pain, related to the adjacent joint. Symptoms are usually present for a relatively long period, indicating that the tumor is of slow growth. A history of trauma can often be obtained, but the importance of trauma in the development of this tumor, as in the development of other bone tumors, is questionable.

The roentgenographic appearance may be suggestive of chondroblastoma if the lesion is in a long bone, but it is by no means diagnostic. The roentgenographic appearance of the lesions in flat bones is more confusing and may suggest malignancy. Periosteal reaction is a frequent and significant finding, since it is not usually seen in benign tumors. Roentgenographically the tumor may be confused with chondrosarcoma, central chondroma, benign giant-cell tumor, and even fibrous dysplasia.

The findings of a physical examination of patients who have chondroblastoma are in no way diagnostic, nor are the results of laboratory investigations. The "suspicion index" should be high, however, when pain associated with a tumor in the epiphysis of a long bone occurs in a young male whose general health is good and in whom symptoms have been present for a long time. Nevertheless, it is always necessary to do a biopsy in order to establish the diagnosis.

The pathological picture of chondroblastoma requires careful evaluation, because errors in diagnosis may lead to overtreatment and even to amputation. The two tumors reported here which represent transitional forms between chondroblastoma and chondromyxoid fibroma emphasize the kinship of these tumors and justify classifying both lesions in the cartilaginous group, as Lichtenstein [17] has done. Occasionally it may be difficult to decide whether a given lesion is a chondromyxoid fibroma or a chondroblastoma, and it seems reasonable to classify the rare "mixed" lesions according to the type of tumor which predominates. In any case, the classification is somewhat academic because of the benign nature of both lesions.

Copeland and Geschickter have discussed a malignant form of chondroblastoma and have described fifteen cases in which this lesion caused death. Malignant types have not been recognized by other investigators, however, and in the present study no malignant changes were observed. All the lesions seen by the authors appeared to be benign, both clinically and microscopically, and, furthermore, a study of the chondrosarcomata and osteogenic sarcomata recorded in the files of the Mayo Clinic has revealed no tumors that could be classified as malignant chondroblastoma. It is the authors' opinion, therefore, that the malignant tumors interpreted by some as being malignant chondroblastomata fall more logically into either the chondrosarcoma group or the osteogenic sarcoma group.

The lesion most commonly confused with chondroblastoma is benign giant-cell tumor. Chondrosarcoma and osteogenic sarcoma are less commonly mistaken for chondroblastoma. The presence of chondroblasts and hyaline matrix with or without focal calcification will differentiate chondroblastomata from benign giant-cell tumors. If evidence of malig-

nancy, such as anaplasia and hyperchromatism of the tumor cells or binuclear cartilage cells, is lacking, chondrosarcoma and osteogenic sarcoma may be ruled out.

The concept that the proliferating cells of chondroblastomata are "chondroblasts" is supported by the results of this study. All of the tumors contained some chondroid ground substance, and in a few cases rather typical hyaline cartilage was found. The fact that chondroblastoma and chondromyxoid fibroma are related morphologically further indicates the ability of the cells in these tumors to produce chondroid material. It is true, of course, that the nuclei of the chondroblasts resemble histiocytes, as has been suggested by Valls and his associates. These authors support their contention that the basic cell of the tumor is a histiocyte by evidence obtained by a silver-staining technique. However, the interpretation of silver stains is difficult when dealing with a tumor in which thin strands and large masses of ground substance are present, and the authors regard the concept that the chondroblasts are differentiated histiocytes as an unproved possibility.

Since chondroblastomata are benign, they should be treated by conservative means. The definite recurrence of one tumor in the authors' series (Case 1) and the possible persistence of another after partial removal and roentgen therapy (Case 14) indicate the desirability of thorough removal of the tumor if possible. It should be noted that the patient who had the definite recurrence was cured by the second excision. Bone grafts may be necessary to fill the defects when larger lesions are resected or excised. Chondroblastomata may respond to roentgen therapy alone (the treatment recommended by Codman), but recent publications by Hatcher, Hatcher and Campbell, Cahan and associates, and others emphasize the ever-present danger of radiation-induced malignant change. For this reason it is recommended that radiation therapy be avoided unless the tumor, by virtue of its anatomical location, is unsuited to surgical excision or resection.

SUMMARY

Benign chondroblastoma is a distinctive lesion of bone. Because of its histological features it falls logically into the group of benign tumors of cartilaginous derivation, in which chondromata, osteocartilaginous exostoses, and chondromyxoid fibromata also belong. The series of cases on which the authors' paper is based demonstrates that there is a close relationship between chondromyxoid fibroma and chondroblastoma.

This study re-emphasizes the benign nature of chondroblastoma and its favorable response to conservative surgical management. No malignant counterpart or malignant transformation of this tumor was encountered by the authors.

Since the patients in this series range in age from the first through the sixth decade, it is evident that the age span of patients with this neoplasm is greater than the literature indicates.

Four instances of benign chondroblastomata in the innominate bones and two of lesions in the scapula represent previously unrecorded sites for this tumor.

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Stress Tolerance of Bone and Metal

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The problem of mechanical failure of devices for internal fixation and of endoprostheses was approached by the direct measurement of loads to failure manifest by bone, metal, and a combination of the two. Studies through the years referred chiefly to the nature of the metals used and to the reaction of the body to these metals [12]. Attention is now directed to the design and fabrication of the devices and to the manner in which they are used by surgeons. Recorded experiences are accumulating concerning the performance, endurance, and failure of these devices in patients.

Critical interest in the design of these devices has developed a belated awareness of the magnitude of stresses involved and of the mechanisms of fatigue failure [9]. The present study, extending over the past several years, concerns one phase of the problem — the direct measurement of static loads to failure of bone and metallic devices used for reinforcement or replacement of bone. Test materials consisted of metal devices of standard manufacture available on the open market and experimental devices made of some of the newer alloys. The bone specimens were random samples of about the same age, of equivalent moisture content, and without apparent bone disease.

During the course of this study, the various methods of stress analysis employed by industry were reviewed and were applied to this problem. It is proper to encourage their use in the design and manufacture of surgical devices.

The primary purpose of this investigation was to determine the intrinsic mechanical strength of bone and of the devices used for the reinforcement or replacement of bone. Objective data derived from standard engineering procedure were obtained. No attempt was made at any time to imitate the complex gravimetric or dynamic stresses imposed in body function, but an attempt was made to obtain a relative evaluation of the strengths of the structure of bone, metallic devices, and a combination of the two.

A classic presentation of data concerning bone strength and the mechanism of fractures about the hip was made in 1953 by the late L. D. Smith of the Department of Orthopaedic Surgery of Marquette University. This study is helpful in any consideration of the perplexing stress problems in hip fractures [11].

The value of static-load testing of bone and of orthopaedic devices may well be questioned [8], but the method has been used as a good indicator of where and when a part will fail under loading. The findings for bone and for orthopaedic devices under identical test conditions are presented as a preliminary consideration. Fatigue testing by cyclic loading is very much to be desired, but technical difficulties have made the results of such testing unsatisfactory and they are not included in this presentation.

Our test methods utilized universal tensile-testing machines which are available in most industrial laboratories. Transverse-bend and compression tests were employed, and loads to failure were expressed simply in pounds. Bone failed by complete fracture with shatter, whereas metal demonstrated bend beyond the elastic range (permanent deformation) (Tables I, II, and III).

The transverse-bend test is used for the evaluation of strength and toughness of hard, brittle material such as tool steel, cast iron, ceramics, and bone. Tension tests become increasingly difficult as the hardness of the material increases, whereas the bend test involves fewer difficulties and is more significant as the hardness increases. The test normally consists in a beam being placed between two anvils and being loaded at the center. Its utility is increased by the simplicity of the test and by the rapidity of obtaining results, since the breaking load serves as a measure of strength.

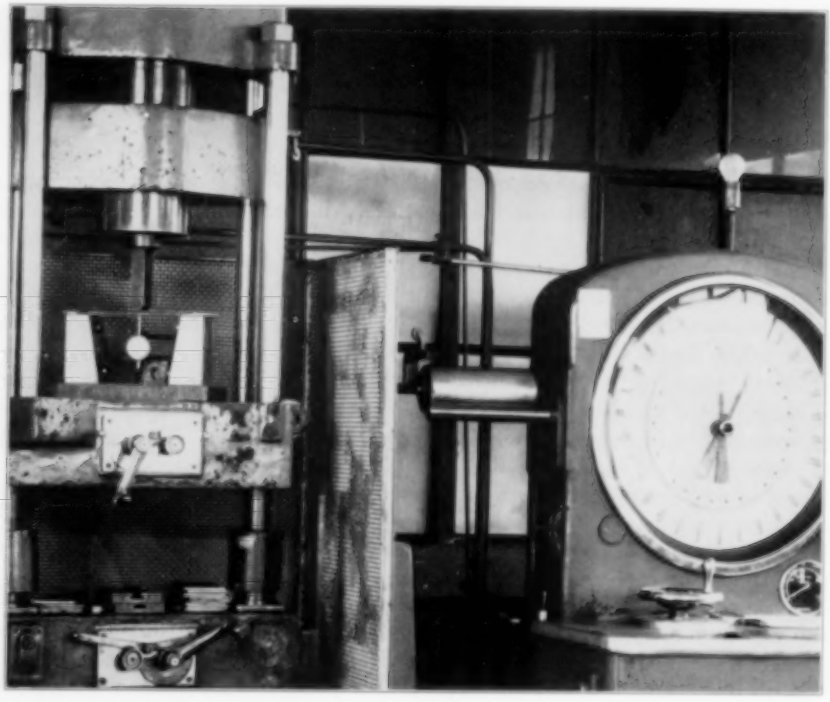

FIG. 1

A heavy-duty tensile-testing machine shown with Hansen-Street bar between anvils (Table II).

A uniform rate of loading was used. This fact is not too important in testing most brittle materials so long as the load remains lower than the speed of shock or impact loading[6].

Transverse-bending loads to failure were applied to cadaver bone by placing the bone ends on anvils and loading at the centerpoint. Tabulation includes a comparison calculated to a common twelve-inch span.

Transverse-bending loads to failure were applied to various metallic devices used in bone surgery in a similar manner (Fig. 1).

Transverse fractures of the mid-shaft in cadaver long bones were fixed by plates and were tested by transverse bending loads to failure. The loads were directed with the fixation device on the lower side of the beam, that is, opposite the point of applied force. The data obtained were adjusted to a common span of twelve inches and were compared with similar data obtained from the testing of intact cadaver bone.

For the femoral neck and the devices used in its surgical fixation and replacement, a load-to-failure test was designed. Metallic devices of comparable size were held in a jig grasping the lower two inches of their shafts. Loads were applied at the tip of the nail or blade in the devices and to the topmost portion of the sphere in femoral heads and prostheses (Figs. 2, 3, 4, and 5). An effort was made to set bone, device, and a combination of the two in anatomical positions previously determined by roentgenographic studies of living patients in a standing position. In this way the force of normal weight-bearing was simulated (Tables IV and V).

Loads to failure in the long axis of bones were not measured. Longitudinal stresses are more adequately resisted by long bones than are angular and torsional stresses. It is relatively rare to encounter failures induced by excessive compression with the exception of axial compression fractures of cancellous bones.

TABLE I

TRANSVERSE-BENDING LOADS ON BONE

Radial shaft	at 9-inch span, 91 pounds:	at 12-inch span, 68 pounds
Humeral shaft	at 12-inch span, 580 pounds:	at 12-inch span, 580 pounds
Tibial shaft	at 14½-inch span, 755 pounds:	at 12-inch span, 912 pounds
Femoral shaft	at 15-inch span, 885 pounds:	at 12-inch span, 1106 pounds

Torsional loads to failure were measured in only a few instances because of the technical difficulty. More study is needed here, for this stress is commonly encountered in clinical practice. The three-inch Sherman plate failed at fifteen inch-pounds of torsion, whereas the Lane plate failed at a load of sixty-six inch-pounds. Simple dynamometry of forearm torque revealed ordinary functional demands, such as the use of a screw-driver or the turning of a door knob, to be greater than sixty inch-pounds. Surgical experience with forearm fractures has amply proved the inadequacy of commonly employed fixation devices.

TABLE II

TRANSVERSE-BENDING LOADS ON ISOLATED METALLIC DEVICES
(ALL SMo STAINLESS STEEL EXCEPT VITALLIUM NAIL)

3-inch Sherman plate	10 pounds	Rush pin (femoral)	150 pounds
3-inch Lane plate	76 pounds	Lottes bar (tibial)	175 pounds
6-inch Sherman plate	47 pounds	Hansen-Street bar	178 pounds
6-inch Eggers plate	120 pounds	4-flanged bar	226 pounds
6-inch Lane plate	165 pounds	Smith-Petersen nail (SMo)	183 pounds
6-inch Collison plate	175 pounds	Smith-Petersen nail (Vitallium)	445 pounds
(1¼-inch bone screws, SMo-type 316 with SAE thread, 150 pounds)			

Shock loading, as commonly encountered in clinical fracture work, is quite difficult to duplicate under test conditions. Although static-load tolerance might be used as a point of reference [6], impact testing and drop tests in which the part to be tested and the load are dropped together, as is done in the testing of aviation landing gear, should receive further consideration.

Studies of failures of sample plates and screws used in orthopaedic surgery revealed failure from fracture or fatigue. Some appeared to fail from the inadequacy of acceptance of the normal or accidental stresses imposed. A few of the metal devices displayed a coarse crystalline structure resulting from incomplete homogenization by heat treatment during their manufacture. Others revealed patterns of fatigue failure related to poor design, crude manufacturing, or the faulty use of instruments (scratch and bend) at the time of insertion.

It is estimated that 90 per cent of fatigue failures of metal occurring in industrial service or during laboratory tests are caused by defects in design and production and only 10 per cent are caused by defects in material specification or heat treatment [6].

Our studies of mechanical failure of endoprostheses continue. Relative evaluations of the strength of bone and devices have been made (Table IV). Focal points of stress have

TABLE III

TRANSVERSE-BENDING LOADS IN FRACTURES WITH FIXATION

Radial shaft with 3-inch Lane plates, 67 pounds	Intact radial shaft 68 pounds
Humeral shaft with 6-inch Lane plate, 102 pounds	Intact humeral shaft 580 pounds
Tibial shaft with 6-inch Eggers plate, 90 pounds	Intact tibial shaft 912 pounds
Femoral shaft with two 6-inch plates, 532 pounds	Intact femoral shaft 1106 pounds

TABLE IV

LOADS TO FAILURE OF FEMORAL-NECK FIXATION AND REPLACEMENT DEVICES

Moore blade-plate	108 pounds	Thornton nail-plate	175 pounds
Jewett nail-plate	108 pounds	Pugh nail-plate	203 pounds
Neufeld nail-plate (SMo)	180 pounds	Blount nail-plate (130 degrees)	380 pounds
Neufeld nail-plate (Vitallium)	200 pounds		
Eicher prosthesis (SMo)	360 pounds	Fractured femoral neck with Smith-Petersen nail (SMo)	350 pounds
Eicher prosthesis (Titanium)	1720 pounds		
Eicher prosthesis (Vitallium)	1870 pounds	Fractured femoral neck with Eicher prosthesis (SMo)	520 pounds
Moore prosthesis (Zimalloy)	1870 pounds		
		Intact femoral neck	1930 pounds

TABLE V

STRESSCOAT TESTS OF UPPER PORTION OF THE FEMUR AND PROSTHESIS
(Loaded in Anatomical Position)

Load	Bone	Vitallium	Titanium	SMo
200 pounds	None	None	None	Present
400 pounds	None	None	Present	Present
Permanent deformation	1930 pounds	1870 pounds	1720 pounds	360 pounds

been revealed by brittle-lacquer coating, and, at higher loads, failure has been demonstrated by permanent deformation. Both the stresscoat method and the permanent deformation of prostheses emphasized weakness in the shaft or stem of the device below the shoulder or angle of the device. This is the point at which most of the failures in clinical practice are encountered. These data emphasize the importance of concentrating the

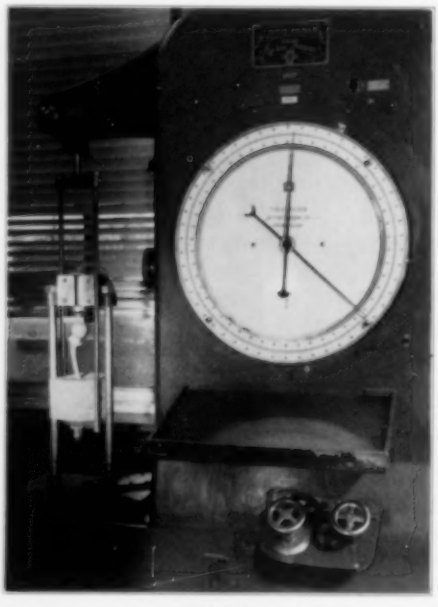

FIG. 2

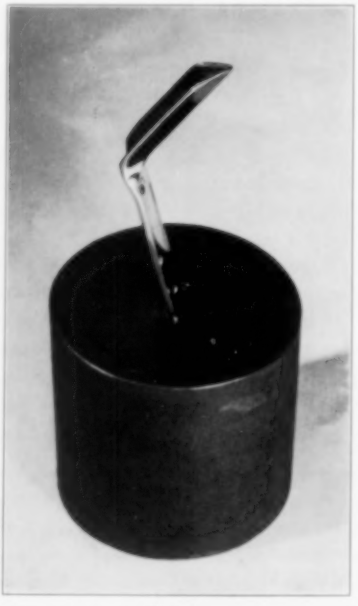

FIG. 3

Fig. 2: A smaller tensile-testing machine shown with a prosthesis under test (Table IV).
Fig. 3: A test sample in the iron jig (Table IV).

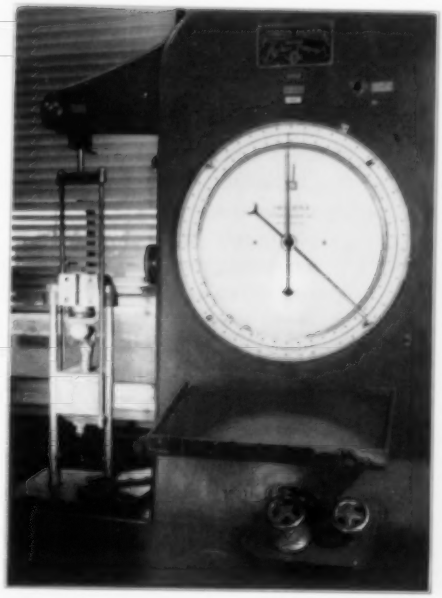

FIG. 4

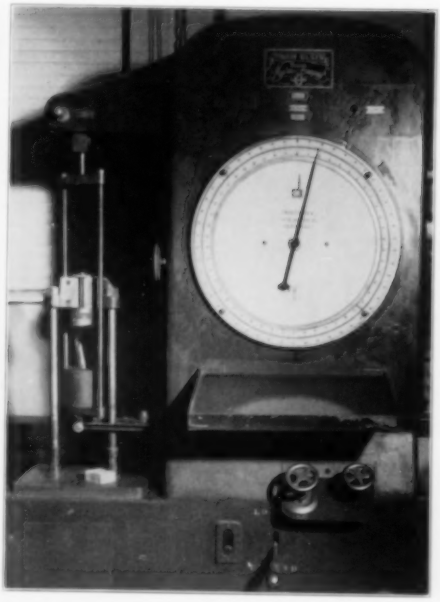

FIG. 5

Fig. 4: Upper portion of a femur mounted in concrete under test conditions.
Fig. 5: Sample nail-plate under test conditions.

majority of the metal in the area where bending stress is most severe. Channelling of the outer radius of the shoulder of the prosthetic stem could well be reconsidered, and breaking of the stem should be preventable by proper design. Dr. E. J. Haboush has calculated and illustrated these stress foci and design errors in his study of prostheses [4]. Further study of the design and actual testing of devices is needed; it seems possible that stresscoat, strain-gauge, photo-elastic, and sonometric methods may all find application.

The remarkable strength of the structure of bone is emphasized by comparison with that of endoprostheses in use at present. This difference is apparently due more to structural design than to the strength of material.

Variation in strength of different femora was noted. In the eight samples in this study the average force required for fracture was 1,930 pounds. In the femora tested by Dr. Smith, the average force required was 2,092 pounds [11]. Many more determinations in healthy and diseased bones of various age groups are necessary before the determination of average strength of the femur can be made.

These findings may be related to two basic considerations. The minimal load upon the femoral head on normal weight-bearing is approximately 2.4 to 2.6 times the body weight or about 400 pounds in an adult [5]. A rule-of-thumb in engineering suggests that fatigue strength approximates 50 per cent of ultimate strength in the steels used by most surgical fabricators [6]. This expression is made with reference to highly polished specimens of low-carbon steels. If the surface has numerous sharp cracks from manufacturing procedure, from use of instruments at insertion, or from chemical attack after installation, the value for fatigue may drop to less than 20 per cent of the ultimate strength [1].

This rule-of-thumb may be shown by plotting the load required to break a material against the number of applications of the particular load. The load required for breakage after a given number of applications falls, but it then levels off at a value of about one-half the load required to break the material with a single application.

Unlike physiological fatigue, the effects of repeated loading cannot be eliminated by

FIG. 6

Upper portion of a femur after testing. Failure occurred at 1930 pounds.

stopping the test occasionally. Permitting the metal part to "rest" while the patient sleeps will not reduce fatigue failure [10].

Since repeated failures have occurred in prosthetic devices and fatigue failure is definitely to be feared, it would appear that the minimal goal in terms of static-load tolerance should exceed 800 pounds.

Fatigue tests simulating service experience should be planned but more must be learned of the "service requirements" of the average human musculoskeletal system. This will require an understanding of the loads upon the anatomical structures under normal use and careful observation of the stress tolerances related to the design and the chosen alloy in the reinforcing or replacement device. Static-load tests do represent one approach commonly employed by stress analysts in mechanical engineering and represent a beginning in this area of "human engineering".

The usual specifications of an alloy help very little in the evaluation of the strength and endurance of a device. Elements of design and surface smoothness are more significant with respect to fracture and fatigue resistance. Specific reference should be made by manufacturers to the load tolerance of every metallic device used in bone surgery.

One doctor, in discussing the breakage of his own design of prosthesis, stated that ultimate breakage from metal fatigue is bound to occur if the patient lives long enough. This is probably not justified, for it seems entirely possible to design a prosthesis with satisfactory endurance limits for average human service loads. If loads are below the critical endurance limits, steel will withstand stress indefinitely with negligible chance of breakage.

Endurance limits (the highest unit of stress at which material can be subjected to a very large number of repetitions without evidence of failure) can be determined and the relationship of ultimate strength of a material can be related to endurance by "factors of safety" which, although again of a rule-of-thumb nature, are of practical value. The factor of safety is the ratio of ultimate strength of the material to the allowable stress; for example, when the whole load or nearly the whole load is likely to be alternately put on and taken off, the safety factor should be five or six [6].

The problem of practical fatigue is removed somewhat from the realm of conventional testing and is resolved into special testing of design, as well as of material. Special studies

of the part for location of levels of stress concentration may well precede the choice of material. The figure of greatest value would be that obtained on a full-sized specimen with the stress concentrations of service. Other considerations might be of transient value, and, at this time, relative evaluations appear to be in order. Later, adequate specifications of the in-service stresses may become available.

The difficult problem of preventing fatigue failures should be approached first by more careful design. Thereafter search for defects in surface finish should be accompanied by efforts to make the devices as free as possible from internal defects. Surgeons must do their part and see that they apply devices in such a manner that the clinical stresses are properly provided for and that they do not create new ones.

Our desire is to know how much work a device will do — that is, how much force it will tolerate over given intervals of time and space. Such determinations appear within the range of calculation by stress analysis without trial and error testing within the bodies of patients.

Fortunately for the orthopaedic surgeon, stainless-steel parts usually have better endurance than other steels because of the metallurgical properties and also because they resist both intergranular corrosion and gross notches due to pitting [2]. Once incorporated in bone, growth and developmental processes are responsive to stress and may proceed rapidly enough to accept dangerous stresses. It is here that design and insertion of the device in keeping with anatomical structure and function, in addition to metallic compatibility with body tissues, are so very important.

Most of the alloys now used for surgical purposes appear to be well tolerated by the body but careful analyses of metal lots are always necessary. The stainless steel generally used is SMo 18–8 to 12 of type Mo. 316. The new Vitallium (Haynes stellite alloy, No. 21) and several other alloys also seem very satisfactory. Titanium is being studied diligently, and its tendency to adapt to bone may make it an ideal metal for prostheses [3, 7]. Eicher prostheses made of titanium have held up well under our tests and appear to be doing well in early clinical application.

Continuing efforts should be made in the development of proper alloys for use in orthopaedic surgery, and the reasonable suggestion has been made that the surgeon should know as much about the material he puts into the patient as he does about the disease he is treating [2].

Certain common errors in surgical method should be noted. Cold bending of devices to fit surgical needs is to be condemned, for it seems possible that a single cold bend may initiate failure in many commonly used metallic devices. Fixation devices should be primarily designed, fabricated, and applied in a mechanical manner to fit the specific pattern presented by the fracture situation.

Re-use of metallic devices, screws, plates, and inserts is dangerous. Even thorough individual stress analysis of each part, a procedure routine to the automotive and aviation maintenance divisions, would probably fail to reveal all of the accumulated stresses which develop within metals as a result of normal use within the body.

The manner in which we drill bone, the type of screws, and the manner of their insertion are important considerations, and the recommendations of the Bureau of Standards in this regard deserve more generalized acceptance. Neither the withdrawal load (115 to 160 pounds) nor the transverse bending load (140 to 160 pounds) of standard screws (SAE thread of SMo stainless steel or Vitallium) are sufficient to care for the calculated stress along the outer cortical radius of the iliofemoral axis. Fracture and pull-out of the blade-plate and outrigger prostheses have occurred frequently in clinical practice.

Recorded experience of the performance of these devices should be accumulated so that an understanding of endurance limits can be achieved. The "estimated life" of these devices would be of the most practical significance in the choice of device, postoperative care, and performance expectancies in our patients.

Further understanding of the normal strength of bone would be helpful. We have tried to measure this mechanically in a sampling manner on cadaver bone, but we still need to learn of the gradient of returning strength in living, fractured bone undergoing repair. The management of a fracture patient demands an understanding of not only how soon the strength of bone returns with healing but also how much strength returns. This inquiry takes us out of the field of ordinary engineering and brings us close to the miracle of healing.

Our findings demonstrate clearly that ordinary surgical fixation and replacement have in all instances been far weaker than the structure of normal bone. It is necessary either to increase the strength of fixation and replacement devices or to depend more definitely upon such external aids as plaster casts, splints, braces, and other forms of protection in the care of clinical problems.

This preliminary study is but one approach of many that should be undertaken in an effort to understand more fully the "human engineering" undertaken by the orthopaedic surgeon. More than amateur endeavor, such as ours, is needed in this area, and we look with grateful anticipation to the projected work of the American Surgical Materials Association which has been planned under the sponsorship of The American Academy of Orthopaedic Surgeons, the American College of Surgeons, and the American Medical Association. This project should receive the sincere and wholehearted support of every orthopaedic surgeon, for it will prove helpful to him, to his patient, and to his friends in the industry which fabricates devices for the fixation or replacement of bone.

NOTE: This study, conducted without cost or sponsor, was made possible through the generous help of friends in the fields of metallurgy and material analysis (John Frantzreb, Paul Ulmer, Ralph Phillips, and Marjorie Swartz). Several fabricators of surgical materials contributed sample devices.

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Fat Embolism

The Prophylactic Value of a Tourniquet

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INTRODUCTION

The number of fatalities which occur following fractures and operations on the skeleton is surprisingly small. This can be accounted for by the steady improvement in the understanding and management of shock, hemorrhage, and infection. As these causes of death are controlled, hitherto less-known causes of fatality assume greater importance. One of these is fat embolism. Since no progress has been made in reducing the number of deaths caused by fat embolism, an increasing proportion of the deaths which occur following fractures and operations are due to this complication. Watson-Jones estimates that 20 per cent of all fatalities following fractures are due to fat embolism, a figure which is in line with the findings of numerous investigations carried out during and after World War II [5,7,8,9,14]. Since no effective method of treating fat embolism has been discovered, effort should be directed toward minimizing the degree of fat embolism which regularly accompanies injury to the skeleton. This can be done by using a tourniquet, whenever possible, in all operative procedures involving bone.

In 1907, Reiner observed that the application of a tourniquet resulted in sequestration of the potentially embolic fat in the injured extremity. In order to prevent this fat from reaching the general circulation, he inserted a cannula into the femoral vein through the saphenous vein prior to removal of the tourniquet. The first wave of blood coursing through the limb was thus intercepted, resulting presumably in elimination of a significant portion of the fat. This procedure was not widely used, but forty years later it was echoed in Newman's suggestion that the profunda femoris vein be ligated in patients with fractures of the lower limb in order that fat embolism might be prevented.

Von Aberle, in 1908, after encountering eight deaths as a result of fat embolism following manipulations, advocated the use of an Esmarch tourniquet. He felt that if a tourniquet is applied prior to manipulation and is removed slowly after the procedure is concluded, the hazard of fat embolism will be reduced. During World War I, Bürger urged that in the field Esmarch tourniquets be applied to patients with multiple fractures or with single fractures associated with other injuries to prevent the entrance of fat into the general circulation while the patient was being transported to the hospital. Ryerson, in 1916, on the basis of his own clinical experience and on the basis of the experiments of Bürger, concluded that the use of a tourniquet was the best method of preventing fat embolism following manipulation or operations on the skeleton.

The work of Caldwell and Huber deserves special attention because their experiments were well designed and their results were conclusive. Massive fat embolism was produced in a group of control animals by crushing the tibiae. In most instances the animals were sacrificed five hours later and sections of the lungs were stained for fat. In these sections, an average of eight fat droplets per field could be seen. In a second group of animals tourniquets were applied to the limbs prior to the crushing of the tibiae and were removed at various intervals afterward. An average of only 3.5 fat droplets per field was found in the sections from the lungs of these animals. Caldwell and Huber concluded that in some

*This investigation was supported by a grant from the Graduate School of the University of Minnesota.

instances the use of the tourniquet proximal to the area of bone injury greatly reduced the amount of fat that entered the lungs. In another series of experiments Bisgard found that the length of time the tourniquet was kept in place influenced the degree of pulmonary fat embolism that occurred after its removal; the longer the period, the fewer the emboli.

Surprisingly enough, the knowledge that the use of a tourniquet in bone operations is of prophylactic value has not been widely disseminated. The only current standard works on surgical technique which mention the value of the tourniquet in this regard are those of Watson-Jones and Fischer, Gohrbant and Sauerbruch.

CLINICAL EXPERIENCE

A study of 100 patients undergoing elective orthopaedic surgery was carried out in order to determine the number of these patients in whom fat droplets, ten to fifteen micra in diameter, could be detected in the blood stream. The droplets were demonstrated by the use of a water-soluble fluorochrome stain and fluorescence microscopy [12]. The presence of such droplets of fat has been considered the criterion for the diagnosis of fat embolism. Blood samples were obtained at the time of induction of anaesthesia, at the completion of the operation before the tourniquet, if any had been used, was removed; and one and two hours postoperatively.

Four types of procedure had been performed upon these patients: operations upon bone without a tourniquet, operations upon bone with a tourniquet, operations upon soft tissue without a tourniquet, and operations upon soft tissue with a tourniquet. The results of the study are shown in Table I.

Of the sixty-two patients for whom a diagnosis of fat embolism was made, only one showed the classical clinical signs of fat embolism during the postoperative period. The remainder had subclinical forms. In six of the 100 patients studied fat droplets were present in the control sample drawn at the time of induction of anaesthesia. Three of these patients had fresh fractures which would account for this finding, but for the other three no satisfactory explanation could be discovered.

A pneumatic tourniquet had been used upon forty-six patients and in five of these patients fat droplets were found in the systemic circulation before the tourniquet was deflated. This would suggest that the compression of the subcutaneous tissue which results from the use of the inflated tourniquet may itself give rise to a mild degree of fat embolism. In the analysis of the data, three questions were proposed:

1. Is the incidence of fat embolism greater in association with operations upon the bone than it is in association with operations upon the soft tissue?

2. Does the use of a tourniquet in patients undergoing bone operations afford any protection against fat embolism?

3. Does the use of a tourniquet itself give rise to any degree of fat embolism?

The answers to all of the questions are affirmative. The probability that the results obtained in this experiment are due to chance alone is less than two in 100.

ANIMAL EXPERIMENTS

Fasting mongrel dogs at least one year old were anaesthetized with pentobarbital (15 milligrams per kilogram of body weight) given intravenously. Fractures of both bones of the leg were produced by snapping the limb over the edge of a vise. These fractures were transverse in type and were not badly comminuted. Blood samples were drawn from the peripheral veins of uninjured extremities or from the jugular vein, and were examined for the presence of fat droplets [12]. At the end of the experiments the animals were sacrificed by exsanguination. A final blood sample was obtained from the right atrium, and frozen sections of the lungs, brain, and kidney were examined for fat emboli, phosphine 3R, a water-soluble fluorescent fat stain, being used [11]. Only the fat droplets which were found within the lumen of a vessel were considered to be fat emboli.

TABLE I

THE RELATIONSHIP BETWEEN THE INCIDENCE OF FAT EMBOLISM AND THE TYPE OF OPERATIVE PROCEDURE USED

Group I	Operations upon Bone without a Tourniquet	
	Spinal fusion	8
	Osteotomy	9
	Arthroplasty	5
	Bone graft	4
	Intramedullary nailing (femur)	5
	Open reduction fracture	7
	Miscellaneous	6
	Total	44
	No. with fat embolism	37
Group II	Operations upon Bone with Tourniquet	
	Arthrodesis	12
	Osteotomy	6
	Amputation	2
	Miscellaneous	11
	Total	31
	No. with fat embolism	18
Group III	Operations upon Soft Tissue without Tourniquet	
	Manipulation	5
	Secondary closure	4
	Revision of wound	1
	Total	10
	No. with fat embolism	0
Group IV	Operations upon Soft Tissue with Tourniquet	
	Steindler stripping	3
	Tendon operations	4
	Meniscectomy	5
	Miscellaneous	3
	Total	15
	No. with fat embolism	7
	Total	100
	No. with fat embolism	62

In the first group of seven animals two blood samples were drawn, one immediately after induction of anaesthesia and one thirty minutes later. The first extremity was then fractured. Thirty minutes later another blood sample was obtained and another extremity fractured. This was continued until thirty minutes after the fourth extremity had been fractured, when the experiment was terminated. The results of this experiment are shown in Table II. It is readily apparent that fat emboli reach the general circulation soon after fracture.

In a second group of eight animals, blood samples were obtained at the time of induction of anaesthesia, and rubber tourniquets (Martin bandages) were applied to all the extremities. Thirty minutes later a second blood sample was removed from the jugular vein and all four extremities were fractured. Further blood samples were obtained sixty and ninety minutes following fracture, after which time the tourniquets were carefully removed. Three blood samples were then drawn at thirty-minute intervals and the experiment was terminated. The results are shown in Table III. It can be seen that as long as the tourniquets remained in place, no fat emboli were able to enter the general circulation.

TABLE II

THE INCIDENCE OF FAT EMBOLI IN THE BLOOD, LUNGS, BRAIN, AND KIDNEYS OF DOGS WITH FRACTURES OF THE EXTREMITIES OPERATED UPON WITHOUT TOURNIQUETS

	Blood Samples (*Time in Minutes*)							Tissue Sections		
Dog	0	30	60	90	120	150	180	Lungs	Brain	Kidneys
1	0	0	+	+	0	0	0	+	+	+
2	0	0	+	+	+	+	+	+	+	+
3	0	0	+	+	+	+	+	+	+	+
4	0	0	0	+	+	+	+	+	+	+
5	+	+	+	+	+	+	+	+	+	+
6	0	0	0	0	+	+	+	+	+	+
7	0	0	+	+	+	+	+	+	0	+

Anaesthesia — Fracture first leg — Fracture second leg — Fracture third leg — Fracture fourth leg

TABLE III

THE INCIDENCE OF FAT EMBOLI IN THE BLOOD, LUNGS, BRAIN, AND KIDNEYS OF DOGS WITH FRACTURES OF THE EXTREMITIES OPERATED UPON WITH TOURNIQUETS

	Blood Samples (*Time in minutes*)								Tissue Sections		
Dog	0	30	60	90	120	150	180	210	Lungs	Brain	Kidneys
1	0	0	0	0	0	+	+	+	+	+	+
2	+	0	0	0	0	+	+	+	+	+	+
3	0	0	0	0	+	+	+	+	+	+	+
4	0	0	0	0	+	+	+	+	+	+	+
5	0	0	0	0	+	+	+	+	+	+	+
6	0	0	0	0	+	+	+	+	+	+	+
7	0	0	0	0	+	+	+	+	+	+	+
8	0	0	0	0	+	+	+	+	+	+	+

Anaesthesia given — Tourniquets applied — Fracture of Extremities — Tourniquets removed

A third group of four dogs was handled in exactly the same manner that the second group had been handled, except that the limbs were not fractured. The only trauma inflicted upon these animals was the application of the tourniquets. From an examination of the blood samples and tissue sections of these animals, a distinct impression was gained that when fat embolism was present in these animals, it was of a lesser degree than that in the animals of the previous experiments (Table IV).

DISCUSSION

The frequency with which fat droplets ten to fifteen micra in diameter are found in

TABLE IV

THE INCIDENCE OF FAT EMBOLI IN THE BLOOD, LUNGS, BRAIN, AND KIDNEYS OF DOGS WITHOUT FRACTURES OPERATED UPON WITH TOURNIQUETS

	Blood Samples (*Time in minutes*)								Tissue Sections		
Dog	0	30	60	90	120	150	180	210	Lungs	Brain	Kidneys
1	0	0	0	0	0	0	0	0	0	0	0
2	0	+	0	+	0	0	0	0	+	0	+
3	0	0	+	0	+	+	0	+	+	+	+
4	0	0	0	0	+	0	0	0	+	+	+

Anaesthesia given; Tourniquets applied; Tourniquets removed

the circulating blood of patients after operations upon the bone suggests strongly that fat embolism, or traumatic lipaemia, occurs regularly in association with trauma to the skeleton. This condition is rarely the cause of any recognizable signs or symptoms in the patient. Yet, when the diagnosis of fat embolism can be made on clinical grounds, the patient is seriously ill and all too frequently expires. The problem here is to determine why a condition which appears to be very common and of little significance in the vast majority of patients may have such serious consequences in a few.

The fat droplets reach the systemic circulation very quickly after the injury to the bone (Table II). It would seem that the source of these fat droplets is the site of the injury since they do not appear in the blood stream until the tourniquet has been removed (Table III). There can be little doubt that the use of a tourniquet is of real value in minimizing fat embolism in patients in whom operations involve trauma to bone. In such cases it should be used wherever possible. The use of a tourniquet for operations upon the soft tissues, on the other hand, has little, if any, value in minimizing fat embolism. In fact, the compression of the soft tissues by the tourniquet may occasionally give rise to a minor degree of fat embolism. In operations upon the bone, the prophylactic value of the tourniquet outweighs this small hazard, but in soft-tissue operations this hazard may well be a reason for omitting the tourniquet when its use can be avoided.

Caldwell and Huber, in addition to demonstrating the value of the tourniquet in reducing the degree of fat embolism accompanying fractures, showed that immobilization of the limb is also effective in minimizing the degree of fat embolism. No attempt was made in the authors' experiments to evaluate the role of immobilization in this regard. The results obtained by Caldwell and Huber were clear-cut, however, and there is no doubt that immediate immobilization of the traumatized limb in a splint or plaster dressing is another effective way in which fat embolism can be reduced. Whenever possible, such immobilization should be instituted before removal of the tourniquet.

The results of this investigation provide further support for the principle, advocated by many, that a tourniquet should be used during the biopsy or excision of malignant tumors in order to prevent the escape of tumor emboli to the lungs during the operative manipulation of the tumor-bearing areas.

SUMMARY

As a result of a method of detecting fat droplets in the circulating blood, it has been possible to make a study of fat embolism in 100 patients undergoing elective orthopaedic surgery. The results of this study have been correlated with the results obtained in experiments on animals. By these investigations it has been demonstrated: (1) that fat embolism

is more frequently associated with operations upon the bone than with operations upon the soft tissues; (2) that the use of a tourniquet in an operation upon bone effectively sequesters fat in the extremity and prevents fat droplets from reaching the systemic circulation; and (3) that the compression of the soft tissues by a tourniquet produces a minor degree of fat embolism.

A tourniquet should be used whenever possible in operative procedures involving trauma to bone because of its value in minimizing fat embolism.

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Functional Bracing of the Arm

Part II

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EXAMPLES OF ARM BRACING AND PRESCRIPTION

In spite of an attempt to avoid the use of an unnecessary amount of material, the following examples are in some instances quite detailed. They are given chiefly for the sake of clarity to those wishing to apply the techniques described in Part I. They demonstrate the major problems and some solutions. The original purpose of the brace must be kept in mind in evaluating its success, as will be readily discovered. There are three general categories:

1. Those braces designed to provide the patient with a satisfactory assisting arm;
2. Those braces designed for the patient with severely involved upper extremities in an attempt to aid in self-care and light activities of the arm;
3. A merging of both types, depending upon the individual problems.

In so far as possible, detailed muscle charts will not be given, and function will be dealt with as its effect upon the motion of the joint as a whole in a given range or direction.

CASE 1. N. G., male, forty-two years old, had suffered a complete brachial plexus injury of the right upper extremity thirteen years prior to fitting.

Functional Analysis

Left upper extremity was normal.

Right upper extremity: The right hand, wrist, and elbow had only the muscles supplied through the ulnar nerve, except for the scapular head of the triceps, which was rated *poor minus*. There was good function of the interossei of the hand with fair profundus strength to the middle, ring, and little fingers. There was a good flexor carpi ulnaris, and there were good hypothenar muscles. The thumb adductor was also good. There was trace contraction of the pectoralis major, but there was no latissimus dorsi contraction or teres major contraction. The scapulohumeral muscles were flail, but the scapulothoracic muscles were normal. Throughout the distribution of the radial and median nerves all muscles except for the weak triceps were paralyzed and no sensation remained. Thus, the thumb and index fingers were totally anaesthetic.

Prescription

Although the outer three fingers and palm had some sensation and motor power, there were none in the thumb and index finger; therefore, a hook would allow a greater degree of function than proper harnessing of the outer three fingers. Since there was a good ulnar wrist flexor, a hinged wrist piece with dorsiflexion lock and elastic wrist extensor was used. (The wrist joints were blocked in 20 degrees of dorsiflexion in order to prevent overstretch of the wrist. This provided the equivalent of a wrist flexion unit.) There was no pronation or supination; these were supplied by pre-positioning a friction joint operated by the opposite hand. The elbow lock could have been an outside alternator shoulder harness operated elbow lock, but for greater simplicity and ease of function a manual locking, variable position elbow joint was used. The patient had no active eversion or inversion of

FIG. 1-A

FIG. 1-B

FIG. 1-C

the shoulder, and the scapulohumeral muscles were paralyzed. Therefore, he was given a friction controlled internal and external rotation joint with a tight-fitting shoulder band, clasping the anterior and posterior surfaces firmly, connected with an over-the-shoulder strap. The elbow hinge was adjusted so that when the joint was unlocked, the elbow was supported at 90 degrees of flexion by means of rubber bands. Thus, the patient could take advantage of his weak triceps for light activities demanding elbow flexion and extension. Harnessing consisted of the application of a chest strap to provide power to open the hook (Figs. 1-A, 1-B, and 1-C).

CASE 2. G. R., nine years after the onset of poliomyelitis, which had resulted in quadriplegia, used a chest respirator for three to four hours each night. The lower extremities were flail, and trunk balance was impaired but adequate.

Functional Analysis

Right upper extremity: There was good flexion and extension of the fingers and thumb. Opposition was rated *zero*. The radial wrist extensors were good; the ulnar wrist extensor was absent. The ulnar wrist flexor was good while the radial wrist flexor was absent. Elbow flexion was rated *fair;* extension, *poor;* both pronation and supination, *fair;* humeral internal and external rotation, *poor;* humeral flexion and extension, *poor;* scapular elevation, *zero;* and scapular forward flexion or protrusion, *poor*.

FIG. 2-A

FIG. 2-B

Left upper extremity: Finger and thumb flexion were rated *good*, but finger and thumb extension were rated *zero*. Wrist extension was rated *zero;* wrist flexion, *trace;* elbow flexion, *poor plus;* elbow extension, *trace;* forearm supination, *good;* forearm pronation, *fair minus* (finger flexors); humeral external rotation, *trace;* internal rotation, *fair;* flexion, *zero;* extension, *poor minus;* scapulothoracic motion, *zero*. In the last, however, there was slight elevation which was accomplished by the clavicular head of the pectoralis major.

FIG. 2-C

Prescription

The patient was provided with a pelvic band and shoulder-hoop suspension bilaterally. Bilaterally humeral cuffs were attached to the shoulder hoops and, bilaterally, elbow suspension from hoops was provided by means of rubber bands. A functional hand brace was applied to the left wrist and hand.

Right upper extremity: The elbow was suspended from the iliac-based shoulder hoop by means of rubber bands which were attached to the forearm cuff. Humeral flexion of 15 to 20 degrees was pre-positioned by the humeral cuff attached by an arm to the shoulder hoop. External rotation was assisted by a rubber-band motor from the elbow cuff to the humeral cuff. A shoulder depressor strap, attached to the shoulder hoop anteriorly and posteriorly with rubber bands, prevented undue scapular elevation at the time of elbow flexion.

Left upper extremity: The elbow cuff was suspended from the shoulder hoop by means of rubber bands. More help was needed for the left upper extremity than for the right. The humerus was pre-positioned in 15 to 20 degrees of forward flexion by means of a humeral cuff attached to the shoulder hoop, the flexion force being provided by rubber

FIG. 3-A

FIG. 3-B

FIG. 3-C

bands. An over-the-shoulder depressor strap was provided in order to stabilize the shoulder on flexion of the elbow. A functional wrist and hand brace of the extensor type was used as a means of stabilizing the wrist and of providing finger extension. Rubber bands, assisting the natural extensor spring built into the brace, were used dorsally at the metacarpophalangeal joints, at the proximal interphalangeal joints, and at the wrist joint. A plastic sheath enclosed the thumb; this was attached with rubber bands to an outrigger on the functional hand brace in order to provide abduction and extension for the thumb. The brace was made with one strap across the palm. The hand brace was eccentrically attached to the forearm cuff with a rubber band motor providing supination.

With this brace, the patient was better able to use her left hand, since active extension to oppose finger flexion was provided. She gained humeral forward flexion and, in this way, increased her work area. The elbow flexion assistance improved elbow flexion and prevented her from tiring quickly. With the brace, she was able to accomplish many activities related to her chosen work as an accountant which she had been unable to perform without the brace. The main advantage of her brace, however, was that she did not tire so easily and was able to work for from four to six hours at a time. Prior to bracing she could only work for thirty to forty-five minutes. At the time of writing she wore her bracing apparatus for the major portion of the day and felt that it was important to her from a vocational standpoint. She was able to take the bracing off herself but could not put it on (Figs. 2-A, 2-B, and 2-C).

CASE 3. R. A., male, eighteen years old, was seen four years after cervical-cord injury which resulted in quadriplegia from the level of the sixth cervical vertebra.

Functional Analysis

The right and left upper extremities showed symmetrical involvement. The patient had excellent scapulothoracic and scapulohumeral muscles. The triceps brachii was rated bilaterally, *poor*, the biceps and brachialis were rated *good*, brachial radialis was rated *fair minus*, and the radial wrist extensor was rated *fair*. There was no finger or thumb motion at all, and hand sensation was poor.

FIG. 4-A

FIG. 4-B

Prescription

Because of the poor hand sensation, previous reconstruction of the hand, consisting in bilateral wrist fusion and transfer of wrist motors and biceps to the fingers, followed by functional bracing of the hand, had not proved satisfactory. The braces were replaced bilaterally to the patient's satisfaction, with Handy Hooks, controlled by a combination of scapulohumeral forward flexion and abduction, harnessed to bilateral axillary and humeral hoops (Figs. 3-A, 3-B, and 3-C).

CASE 4. E. H., thirty-two years old, was seen two years after the onset of poliomyelitis which resulted in quadriplegia.

FIG. 4-C

Functional Analysis

Right upper extremity: Flexion and extension of the fingers and thumb were good. Elbow extension and flexion was rated *poor minus;* scapulohumeral function, *trace;* internal rotation, *poor;* external rotation, *trace;* and scapulothoracic function, *trace.*

Left upper extremity: The extremity was flail throughout.

Neck: Sternocleidomastoid function was good and was partially supplemented by the weak scalenes. Functionally there was good rotation and flexion of the neck.

Prescription

A pelvic band, shoulder-hoop suspension bilaterally, an arm brace for the left extremity, and right-elbow suspension were prescribed. The right elbow was suspended by means

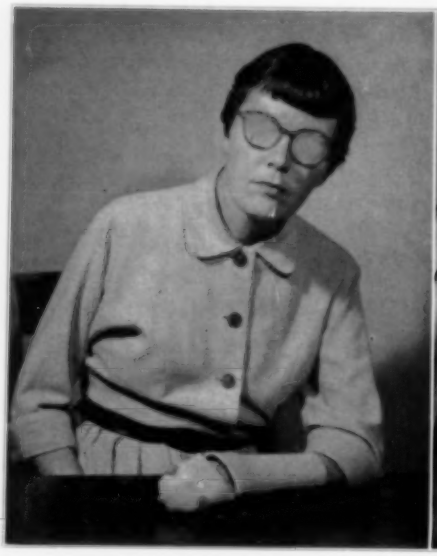

FIG. 5-A

FIG. 5-B

FIG. 5-C

of rubber bands connecting the elbow cuff to the anterior arm of the shoulder hoop. External rotation was aided by an elastic motor which passed from the lateral (over the shoulder) arm of the shoulder hoop to the region of the medial condyle. Shoulder flexion of 5 to 10 degrees resulted from the elastic aid to external rotation so that no upper arm cuff was necessary to give shoulder flexion. With this support, the function of the right upper extremity was markedly improved; and the right hand could operate the left arm brace, placing that arm in the desired positions of pronation, supination, internal rotation, external rotation, and elbow flexion. The left arm was supplied with an arm brace consisting of a Handy Hook and a manually operated variable position elbow lock. Pre-positioning of pronation and supination and internal and external rotation was done manually. Because of the flail scapulohumeral and scapulothoracic muscles, the weight of the left arm brace was suspended by means of rubber bands from the left shoulder hoop. Suspension was so arranged that it pre-positioned the shoulder in slight flexion. Hook opening was accomplished by chin pressure against a platform attached to a four-inch lever arm and in turn to the shoulder cap just in front of the humeral head. The lever arm was long enough to operate the hook easily with the strong neck muscles (Figs. 4-A, 4-B, and 4-C).

CASE 5. P. K., thirty-five years old, was seen thirty years after onset of paralysis resulting from poliomyelitis.

Functional Analysis

This patient had been operated on twenty years prior to being seen for the prescription of bracing. At that time the following procedures had been done: shoulder arthrodesis bilaterally, arthrodesis of left elbow at 100 degrees; arthrodesis of the left wrist in 10 degrees of dorsiflexion and in 15 degrees of pronation. A Steindler advancement had been done on the right upper extremity as a result of which the patient could lift fifteen pounds. The patient had a good right hand and a flail left hand.

Prescription

A hand brace, consisting of a hard plastic shell over the fingers and thumb with closure of the opposed thumb against the fingers provided by rubber bands, was prescribed. The shell was so made that plastic touched plastic unless an object was held in the hand. This was designed merely as a holding and assisting brace which would allow a limited number of two-handed activities. Any other motor power would have to be provided from the leg; the patient was too well off functionally for her to be willing to put up with the annoyance of leg-controlled apparatus (Figs. 5-A, 5-B, and 5-C).

CASE 6. T. G., male, thirty-two years old, was seen four years after paralysis resulting from poliomyelitis.

Functional Analysis

Right upper extremity: The only remaining active motors in the right upper extremity were a supinator, rated *fair*, and the extensor indicis proprius, rated *fair*.

Left upper extremity: In the left upper extremity the remaining motors were the trapezius, rated *fair;* serratus magnus, rated *poor;* infraspinatus and teres minor, rated *fair;* and biceps, rated *fair*.

There was no involvement of the lower extremities.

Prescription

A reciprocator for elbow flexion and a Handy Hook were provided for each extremity. The reciprocators which were used to supply elbow flexion and slight shoulder flexion were operated by hip and knee motion. The hooks were operated by plantar flexion of the feet. The reciprocators in use on this patient were not true reciprocators, but had similar features to those now in use. The reciprocator as it has now been developed would be superior. However, in this instance, the patient wore a leg brace to which a grooved rod was attached in the line of the lower portion of the leg. The grooves in the rod served to provide varying cable lengths by the catching of a spring-operated tooth or dog. Once the lock had been released, the adjustable cable device was drawn from the knee toward the foot piece by a spring over the rod ratchet. When the proper cable length had been chosen by the patient and the cable-length position had been secured by the grooved rod, the elbow was flexed either by hip extension or by knee extension. Gravity provided extension. Fixed points were provided on the leg ratchet selector, the pelvic band, and the anterior arm of the shoulder hoop from which the forearm brace was suspended. Hook opening was accomplished by plantar flexion of the foot against a fixed point on a calf band of the brace. A separate cable was necessary for this. Hooks were attached to the wrist and forearm braces that provided stability; these braces were suspended from the padded split pelvic band carrying the shoulder hoops of steel wire. The hook cable was secured to the waist band from a floating cable suspension attachment in order to prevent cable wandering, and was passed over the shoulder. The elbow cuff and wrist hook unit were suspended from the anterior arm of the shoulder hoop. The over-the-shoulder portion of the action arms in this case were padded to act as shoulder depressor straps where they crossed the top of the

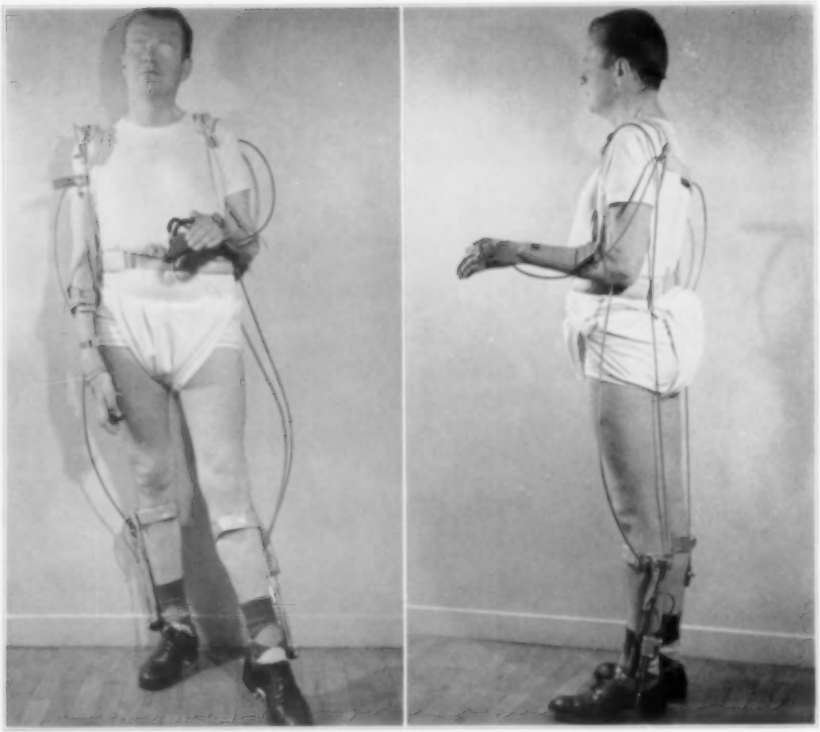

FIG. 6-A FIG. 6-B

shoulder. On the left side, which had good external rotation control, the forearm brace was carefully balanced at the pivotal point (depending upon the weight of the forearm and the brace) which in this case was three and one-half inches distal to the medial epicondyle. The cable was so attached that the arm fell into internal rotation and into slight pronation. The active external rotator then pulled the arm into external rotation and gravity provided internal rotation. The biceps acted to assist proper positioning of the forearm. The left serratus magnus provided enough forward shrug to add additional shoulder position.

On the right side, bracing was identical except that here there were no shoulder rotators and no trace of a biceps assisting motion. The arm was suspended in line with the coracoid process, which tended to make the forearm and hand fall into slight internal rotation. The pivotal point was ignored and the elbow was suspended four and one-half inches anterior to the medial epicondyle, allowing it to fall and not to swing to and fro. Enough shoulder flexion occurred with elbow flexion, so that no special provision was needed for shoulder flexion. A strap was placed between the anterior and posterior arms of the steel hoop at about the level of the deltoid. This maintained the arm in internal rotation and prevented external rotation, except when the patient leaned against it, at which time it caused slight external rotation. Here it was essential to maintain some internal rotation so that the hand would fall into a more useful position. Because he had good supination, the arm was allowed to fall into a pronated position. Since the patient has been using his braces, his shoulder rotators have greatly improved and the biceps which was rated *trace* is now rated *fair*. With the apparatus, the patient can operate a typewriter and use a telephone; he can write and feed himself. This made it possible to train him

FIG. 6-C

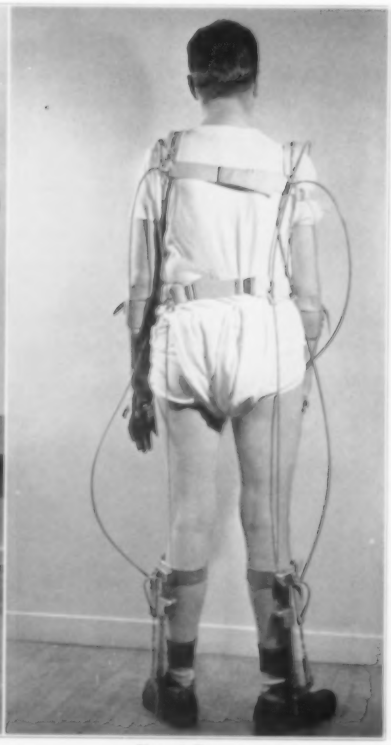

FIG. 6-D

successfully in real estate and insurance problems; he is now earning a satisfactory living (Figs. 6-A, 6-B, 6-C, and 6-D).

CASE 7. N. Y., male, nineteen years old, was seen three years after the onset of paralysis resulting from poliomyelitis.

Functional Analysis

Right: The muscles of the right foot, knee, hip and of the lateral portion of the trunk were graded from *good* to *normal*. There was a completely flail right upper extremity except that the serratus magnus was rated *fair*.

Left: The left lower extremity was flail, although the muscles of the lateral portion of the trunk were rated *good*. In the left upper extremity there was no opponens. Thumb flexion and finger flexion were poor, although thumb and finger extension were good. There was poor wrist flexion with no wrist extension, no pronation, and only poor supination from the biceps, which was rated *fair*. Elbow flexion was fair and elbow extension was poor. Internal rotation of the shoulder was rated *poor minus;* external rotation was rated *trace;* and shoulder extension was rated *trace plus*. Scapular elevation was poor with forward scapular thrust being rated *trace*.

Prescription

A reciprocator was prescribed to provide elbow flexion for the right upper extremity and to operate a Handy Hook. A split pelvic band and shoulder action hoops provided a working foundation. A short brace on the right leg carried the reciprocator box and

[Fig. 7-A

Fig. 7-B

Fig. 7-C

plantar-flexion hook lever. Plantar flexion provided the power to open the hook, while knee or hip extension flexed the elbow. The elbow suspension point was in line with the acromioclavicular joint and lay immediately over the forearm pivotal point in order to provide lift direction. Because of the weight of the forearm brace and hook, the pivotal point of the forearm for elbow motion was slightly distal to the radial tuberosity. Rotation was partly controlled by tilting the body inward or outward. Scapular rotation would allow a forward placement of the scapula and some inward rotation. A pronation and supination unit was not included in the prescription of the bracing, since neither the shoulder nor the opposite arm could be used for positioning these motions. A strap was placed posteriorly between the posterior action arms of the shoulder hoop in order to prevent the action bars from slipping.

Left upper extremity: The left shoulder was pre-positioned in flexion by means of a spring which was tightened from within and which could be adjusted in from 5 to 15 degrees of shoulder flexion. The spring was

fixed to the posterior arm of the shoulder hoop and was attached to an upper arm cuff. Since the patient had internal rotation, elastic motor power was placed from the elbow cuff to the posterior acromial flair of the action bar in order to provide force for external rotation. Since the patient had elbow extension, elastic motors were attached from the anterior arm of the shoulder hoop at a point halfway between the coracoid process and long head of the biceps to allow the elbow cuff at the pivotal point of the forearm to assist in elbow flexion. The forearm and hand unit provided was a hand brace attached to a wrist brace, covered with plastisol. Rubber-band motor power was used to assist weak finger flexors. The Handy Hand was opened by active finger extension. Pronation was secured by attaching the forearm cuff laterally and allowing the unit to fall into pronation. Supination could be achieved from this position by the biceps. The wrist was stabilized with rubber bands. The thumb was brought into opposition with a leather strap pulling toward the pisiform. Elastic finger flexion must not be too strong or the fingers will flex past the fixed thumb position. By floating the weak but active elbow flexor, function was markedly improved, since the weight of the forearm was practically eliminated. The active elbow flexion thus gained allowed the use of the functional hand brace, without which the patient had no function of the hand.

With the use of this apparatus, the patient was able to accomplish the following previously impossible functions: he could feed himself with spoon and fork and drink from a glass or cup; he could brush his teeth, shave with an electric razor, comb his hair, and wash his face. He could also write legibly, type on an electric typewriter, use a telephone, and undress himself. Trunk stability was improved; this greatly aided walking (Figs. 7-A, 7-B, and 7-C).

CASE 8. F. K., female, eighteen years old, was seen four years after the onset of paralysis resulting from poliomyelitis.

Functional Analysis

Left upper extremity: There was no opponens, but the muscles of the hand and wrist were rated *fair* throughout. There was full pronation with good supination and there was good elbow flexion with fair elbow extension. Both internal and external rotation of the shoulder were rated *poor*. Shoulder flexion was rated *trace* and shoulder extension *fair*. There was no abduction. Scapular elevation was rated *poor*, but scapular forward thrust was rated *fair plus*.

Right upper extremity: There was a fair to good hand and fair to good wrist pronation-supination motor. The elbow flexor was rated *fair plus* and the elbow extensor was rated *poor*. The internal rotators were rated *poor* and the external rotators were rated *trace plus*. Humeral extension was rated *poor plus* and humeral flexion, *zero*. Both scapular elevation and forward thrust were good. The lower extremities were flail and the muscles of the trunk were weak. (It will be noted that this girl had functional elbow flexion and extension, as well as functional wrist and finger muscles on the right side. The scapulohumeral muscles were not functioning, although the scapulothoracic muscles were fairly good. On the left side, it will be noted that her elbow, wrist, and hand could function, but the shoulder could not function, although the scapular muscles on this side were rated *fair*.) She did not need hand appliances, but certainly did need something to hold her shoulders in a position of function. Shoulder arthrodesis, bilaterally, might have been considered, but since the lower extremities were flail and the muscles of the upper extremities were rated *poor*, it seemed unwise to limit her motion if this could be avoided.

Prescription

A padded pelvic band and steel-wire hoops over her shoulders were provided. The posterior arms of the action hoops were locked with a stabilizing wire in order to maintain

FIG. 8-A

FIG. 8-B

FIG. 8-C

the proper spacing of the action hoops which carried the humeral flexion device. A cuff was attached to a shoulder-hinge joint which was activated into shoulder flexion by means of a posterior lever arm which extended from the shoulder hinge and was attached by an elastic motor to the posterior arm of the shoulder hoop. The entire device rotated upon a joint which allowed a full arc of rotation and some abduction. By this method the humerus could be held in a position of approximately 20 degrees of foward flexion; this greatly increased the useful range available for elbow and hand activities. The degree of forward flexion was controlled by the active backward flexor of the humerus or, in other words, the extensors of the humerus. The right and left arms were treated in the same manner.

After bracing, strength of elbow flexion in this patient increased, especially at the right elbow, where it progressed from a rating of *poor* to *fair*. On the left, elbow flexion progressed from a rating of *fair* to *good*. She gained shoulder extension and a great deal more shoulder stability. She could get into and out of her braces alone. Previously, this girl had stopped trying to work with her arms except in a very small area in front of her because she had no forward flexion of the shoulders. After being fitted with arm braces, her working area was much wider because of humeral pre-positioning. Strength in her arms increased to such an extent that, at the time of writing, the braces were no longer necessary; she could do with her own muscles the things that the braces had made possible. Previously, her arms were always at her

FIG. 9-A

FIG. 9-B

sides, and she was able to crawl her hands away from her, using the fingers to cross the table top. She could not actively push her arm about the table. She wore her braces for about six months before sufficient strength returned to enable her to discard them. The usual shoulder suspension and daily habit-type work done at a rehabilitation center were employed for almost a year before braces were prescribed. During this period she had made some progress, although it was nowhere near as rapid progress as that made after bracing. When the braces were first delivered, she wore them for six and seven hours a day. At the time of writing, she used her braces only for certain activities. F. K. at that time was enrolled in a junior college for training as a court reporter (Figs. 8-A, 8-B, and 8-C).

FIG. 9-C

CASE 9. P. M., female, fifteen years old, was seen four years after the onset of poliomyelitis.

Functional Analysis

Right upper extremity: Scapular forward thrust (serratus magnus) and elevation (levator angulae scapulae) were rated *fair plus*. Shoulder extension was poor and both shoulder forward flexion and abduction were rated *zero*. Internal and external rotation were rated *trace*. Elbow flexion was graded *poor*, and elbow extension was graded *fair minus*. Pronation was fair, although supination was graded *trace*. Wrist flexion was rated *fair* and wrist extension was rated *good*. Both finger and thumb flexion and extension were

TABLE I

With Braces	Without Braces
1. Flex both right and left elbows	1. Cannot flex left elbow, can flex the right slightly with no assistance
2. Perform some internal and external rotation	2. Cannot
3. Extend her left wrist	3. Cannot
4. Can feed herself	4. In all eating activities must lean arms on table
5. Lift and drink from small glass	5. Cannot drink from a glass without a straw
6. Put on make-up and brush hair	6. Can put on make-up and comb hair, but needs to support arms on something
7. Turn pages in a book	7. Can turn pages of a book only by leaning arms on table
8. Use electric typewriter	8. Cannot use typewriter
9. Use posting machine and lift statements from tray at work	9. Cannot do these activities at all

rated *good*. The thumb abductor was rated *good*, but neither the opponens nor the adductor was present.

Left upper extremity: Scapular forward thrust was rated *poor plus*, although scapular elevation was rated *fair*. Shoulder flexion, extension, and abduction were graded *zero*, and both internal and external rotation were rated *poor minus*. Elbow flexion was rated *poor minus* and elbow extension, *trace*. Pronation was rated *trace* and supination, *zero*. Both wrist flexion and extension were graded *trace*. Finger flexion was rated *zero*, while extension in the third and fourth fingers was rated *good* and extension of the index finger was rated *trace*. Thumb flexion and extension were both poor and there was no opponens.

The muscles of the neck were rated *good* throughout; the lower extremities were flail.

As has been noted, this girl had a functionally satisfactory right hand and wrist, including pronation, with functionally flail right scapulohumeral muscles. Only a portion of the scapulothoracic muscles was functionally satisfactory. On the left side, the hand, wrist, elbow, and shoulder were flail, although there was some ability to elevate the left shoulder. Forward positioning of the shoulder was rated *poor*.

Prescription

A split pelvic band with wire hoops over her shoulders was prescribed. On the right a shoulder-depressor strap, one and one-half inches wide, was used to fix the scapula in such a manner that the elbow can be flexed without the entire arm being lifted. The strap was held to the stainless-steel over-the-shoulder hoop both anteriorly and posteriorly with rubber bands. (Elasticity is essential for the shoulder-depressor strap. It must not be fixed rigidly in order that it may allow forward body motions as well as forward scapular motions.) Since internal rotation was slightly more easily accomplished in this girl, an external rotation rubber-band motor was provided. The forearm was suspended in a cuff so attached that the elastic motor joined the cuff at the exact pivotal point of the forearm. Thence it was led to the anterior action arm in line with the long head of the biceps. (If this suspension point were placed more medially over the coracoid process, the arm would fall into internal rotation, rather than into external rotation.) Since the anterior arm was bent forward at the anterior axillary fold, the wire hoop fell directly over the pivotal point. This allowed not only a direct lift for the forearm in elbow flexion, but served to pre-position the shoulder at approximately 5 degrees of shoulder flexion. On the left, the same hoop arrangement and forearm suspension was used except that, with the forearm and hand brace, the fulcrum was approximately one-half inch more distal on the forearm. The left forearm was fitted with a stainless-steel brace covered with plastisol. The hand and wrist portions were attached with a spring coated with rubber and were locked posteriorly with a

FIG. 10-A

FIG. 10-B

rubber band acting to assist wrist dorsiflexion. The spring joint held the brace in neutral position. A palmar strap was provided to help keep it applied to the wrist and metacarpals. An opponens strap was used at one time on the brace, although it was not being used at the time of writing. Without the assisting wrist brace, the wrist tended to hang in palmar flexion and the patient was unable to use her wrist in any activity. She could use her finger extensors to extend her wrist partly. This brace allowed a flexible position from which finger flexors could function satisfactorily; it took the place, in some ways, of the pre-positioning and stability which might have been attained by a wrist arthrodesis. Some wrist motion, however, was allowed. Because of tendency of the patient to fall toward the left side when she was not wearing her brace, she needed an underarm crutch and corset support in order to stabilize her body position. With the brace, however, this support was not necessary. A buckled webbing strap was also placed posteriorly between the action arms to keep the steel hoops in their proper position. The elbow mechanism was practically identical on the two sides.

FIG. 10-C

In discussing the value of the brace with the patient the following points were brought out: the patient said that she was able to put her braces on partly and to remove them independently in seven minutes. Since receiving the braces, she stated that she had made

great improvement toward functional independence. Not only was she able to perform more things while wearing her braces, but she had discovered that they helped to strengthen her arm muscles to a point where she was able to do more of her own dressing and undressing. These braces also gave her a great psychological boost as she was rapidly able to accomplish things which had previously been beyond her capacity. During the summer following the application of her braces, she had a posting job and found them very helpful. Table I shows what she can do with and without her braces (Figs. 9-A, 9-B, and 9-C).

CASE 10. S. S., eleven years old, was seen after the onset of paralysis resulting from poliomyelitis.

Functional Analysis

Right upper extremity: On the right upper extremity there was a good hand and wrist. Elbow flexion, which had been reinforced by a Steindler procedure, was rated *fair plus;* and internal and external rotation of the shoulder was rated *fair plus.* There was no power in the scapulohumeral muscles, but both scapulothoracic elevation and forward shrug were rated *good.*

Left upper extremity: The left upper extremity was flail, except that scapulothoracic forward flexion and elevation were rated *good.*

The lower extremities were normal.

Prescription

The right upper extremity was functioning satisfactorily; even though it was not normal it needed no supplementation. For the left upper extremity, an arm brace was prescribed. This was a Handy Hook attached to a hand-and-wrist brace. Pronation and supination were controlled by a friction joint. Elbow motion was provided manually by the opposite hand and was locked with a manually operated variable position lock. Internal and external rotation were controlled by manual operation of the friction joint, and the brace was secured to the shoulder by a formed band and leather suspension strap. A chest strap held the brace to the body. The hook was operated by means of a cable and housing from a left groin strap to the posterior portion of the formed shoulder band. The elevation of the left scapula against the groin strap provided the power to open the hook.

With this brace, the patient was able to accomplish many of the activities requiring two hands that were previously impossible.

Osteochondritis Dissecans of the Ankle Joint

Report of a Case Simulating a Fracture of the Talus

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The literature on osteochondritis dissecans is too well known to need review. Since the original articles of Paget, König, and others, many theories as to etiology and pathogenesis have been proposed. Of these the most important are: (1) trauma alone[1, 3, 7]; (2) trauma, followed by a pathological process[5] originally described by Paget as "quiet necrosis"; (3) embolism with secondary infraction and aseptic necrosis; and (4) hereditary, constitutional, or abnormal growth factors[8].

Early, the majority of authors believed that all cases should be treated by surgery[1, 3]; this is still the opinion of many[2, 10, 11, 12]. Recently, however, a number of authors reported successful results from conservative treatment designed to immobilize the involved joint[4, 13].

This case is reported because the patient was seen early following a definite injury, when changes as seen by roentgenogram were minimal, because he was kept under close observation for five months, and because he was rechecked by means of roentgenograms two years later. During the five-month period of observation his condition was treated as a fracture with a weight-bearing plaster boot, and roentgenograms were made at regular intervals. These demonstrated changes progressing from an almost insignificant sclerotic line in the trabeculae of the talus to the classical picture of osteochondritis with loose-body formation. Following the development of the loose body, union began to occur. At this point, the cast was removed for nineteen days, and the roentgenograms promptly

Fig. 1

Roentgenograms made on October 19, 1953, showed minimal changes in the superolateral corner of the body of the talus.

FIG. 2

Roentgenograms made November 20, 1953, showed slight separation and increased sclerosis. A cast was applied on this date.

FIG. 3

Roentgenograms made December 2, 1953, showed the classical picture of osteochondritis dissecans. The zone of separation was enlarged and the area of sclerosis was further increased.

showed evidence of regression to non-union with loose-body formation. The cast was then reapplied, and union subsequently occurred. This lends support to the theory of trauma alone as the etiology of osteochondritis dissecans and to immobilization as the means of treatment before the stage of established non-union is reached.

FIG. 4

Roentgenograms made December 12, 1953, showed the beginning of union and the obliteration of the zone of separation.

FIG. 5

Roentgenograms made January 5, 1954, showed that union was nearly complete. At this time the cast was removed.

C. E. H. (49986) twenty-one years of age, seaman, United States Navy, who had never previously had symptoms referable to the left ankle, sustained a severe varus sprain of this joint on July 26, 1953, while wrestling with his brother aboard ship. He had immediate pain, swelling, and limp, and immediately reported to sick-bay for therapy. During the ensuing nine weeks, he received conservative treatment consisting in

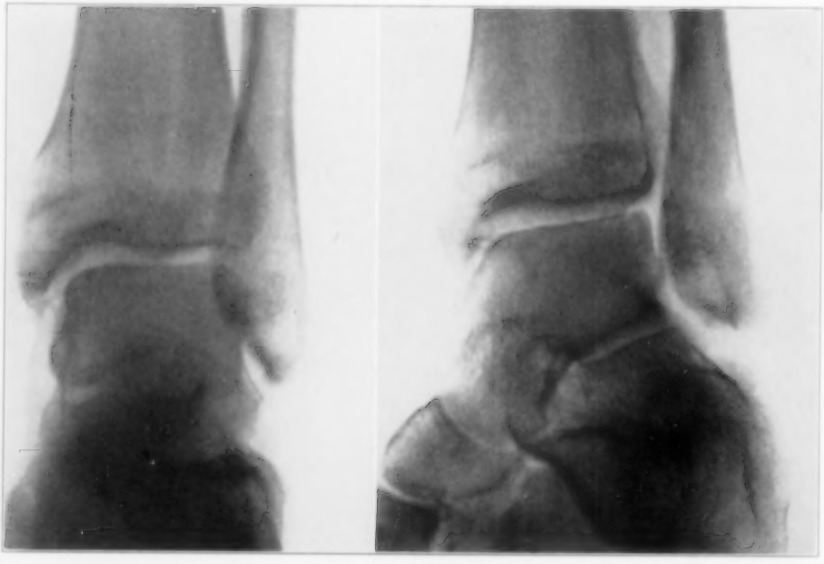

FIG. 6

Roentgenograms made January 22, 1954, showed definite regression toward non-union and loose-body formation. At this time the cast was reapplied.

FIG. 7

Roentgenograms made March 11, 1954, showing that solid bony union had been obtained and that the articular surface of the talus had been restored. The patient was released from plaster on this date and remained symptom-free during the ensuing month, after which time he was returned to duty.

FIG. 8

Fig. 8: Roentgenogram, made September 30, 1955, two years after the onset of osteochondritis dissecans, showed no evidence of recurrence.

intermittent taping, heat, and the application of casts. A roentgenogram of the left ankle made thirty days after injury aboard ship was reported as normal. He continued to have pain and swelling and was admitted to United States Naval Hospital 3923 on October 17, 1953, approximately three months after injury.

General physical examination was normal. There was swelling of the ankle and tenderness along the anterior border of the lateral malleolus. All motions were restricted, and plantar flexion was especially painful in the area of tenderness. Laboratory tests (complete blood count, sedimentation rate, and urinalysis) and a roentgenogram of the chest were normal. Roentgenograms (Fig. 1) made on October 19, 1953, showed that there were two concentric bands in the superolateral corner of the talus, the peripheral being sclerotic and the central osteoporotic. The enclosed island of bone appeared normal. Roentgenograms, made a month later on November 20, 1953, demonstrated a definite zone of separation and showed that the nidus had become sclerotic. A weight-bearing plaster boot was applied on this date. On December 2, 1953, the nidus appeared to be separating, producing the classical picture of osteochondritis dissecans (Fig. 3).

On December 12, 1953, there were definite signs of beginning union (Fig. 4), and by January 5, 1954, the fragment appeared to be fairly well united (Fig. 5). At that time, he was released from the cast and was allowed to walk. The pain, swelling, and tenderness reappeared, and roentgenograms (Fig. 6) made on January 22, 1954, showed regression toward non-union and separation. The cast was immediately reapplied and serial roentgenograms made in February demonstrated progression toward union which was established by March 11, 1954 (Fig. 7). At this time, the patient was released from plaster. On April 5, 1954, he returned to duty. Since that time, he has remained symptom-free. A follow-up roentgenogram, made on September 30, 1955, demonstrated no evidence of recurrence.

DISCUSSION

This case, which had all of the classical findings of osteochondritis dissecans of the ankle, appeared to have the characteristics of a fracture, as has been noted elsewhere [7, 14]. The patient was seen early, and a complete series of roentgenograms was made which demonstrated that the condition responded well to immobilization, regressed when immobilization was removed too early, and finally responded and healed when sufficient immobilization was again applied. From this, it might be assumed that, in the ankle, osteochondritis dissecans with loose-body formation represents either a fracture that is progressing toward non-union or a fracture in which non-union is already established. It also indicates that the changes are reversible with immobilization if this is started before true non-union is present and is maintained until union is secured.

NOTE: It is a pleasure to acknowledge the assistance of John G. Kepler, Librarian of United States Naval Hospital 3923, without whom this paper could not have been written.

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(Continued on page 884)

Sterilization of Preserved Bone Grafts by High-Voltage Cathode Irradiation

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This experiment to be reported was performed to investigate the feasibility of sterilizing homogenous-bone grafts with high-voltage cathode irradiation. If satisfactory, this procedure would facilitate the procurement of bone from fresh cadavera by minimizing the need for detailed sterile autopsies. In the Tissue Bank, Naval Medical School, approximately 20 per cent of all tissue grafts are bacteriologically contaminated during procurement and are discarded. High-voltage cathode irradiation as a means of sterilizing biologicals [6,8,9,10,11] and arterial grafts [7] is well documented.

The mechanism by which ionizing radiations (x-rays, protons, neutrons, electrons) result in the destruction of bacteria is not completely understood. It is known, however, that when ionizing radiations are passed through organic molecules, a primary or direct action of ionization occurs which results in molecular degradation, denaturization, or depolymerization. The manner of bacterial destruction is probably the direct action of ionization on the chromosomal nucleoprotein which results in lethal mutation or preven-

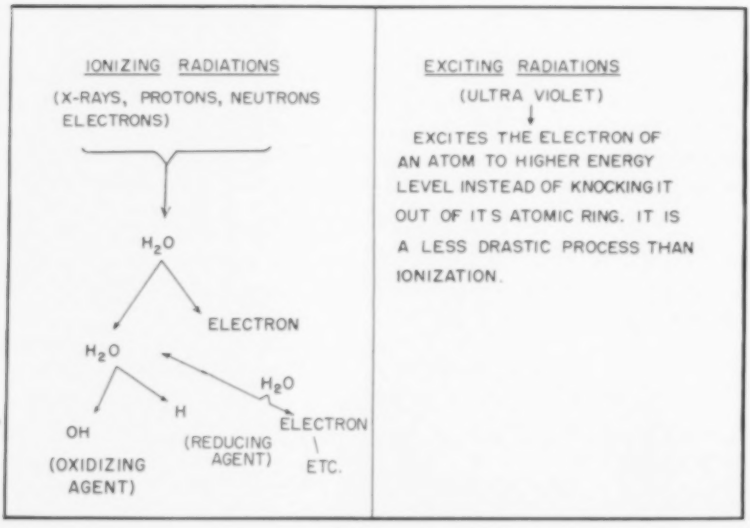

FIG. 1

Ultraviolet rays are merely exciting radiation, while ionizing radiations have a much more drastic effect on organic materials, probably by: (1) a direction action of ionization causing the molecules to undergo degradation, denaturization, or depolymerization, and (2) a secondary action by the ionization of water molecules in the organic material resulting in liberation of free radicals capable of oxidation and reduction reactions as shown above.

tion of reproduction[6-10]. Another important, although secondary effect, is the indirect action brought about by the ionization of water molecules in or around the organic material [10]. This leads to the production of free radicals (hydrogen atoms and hydroxyl radicals) (Fig. 1). The resulting oxidation and reduction reactions are destructive to tissue matrix as well as to bacteria, but these tissue changes may be minimized by per-

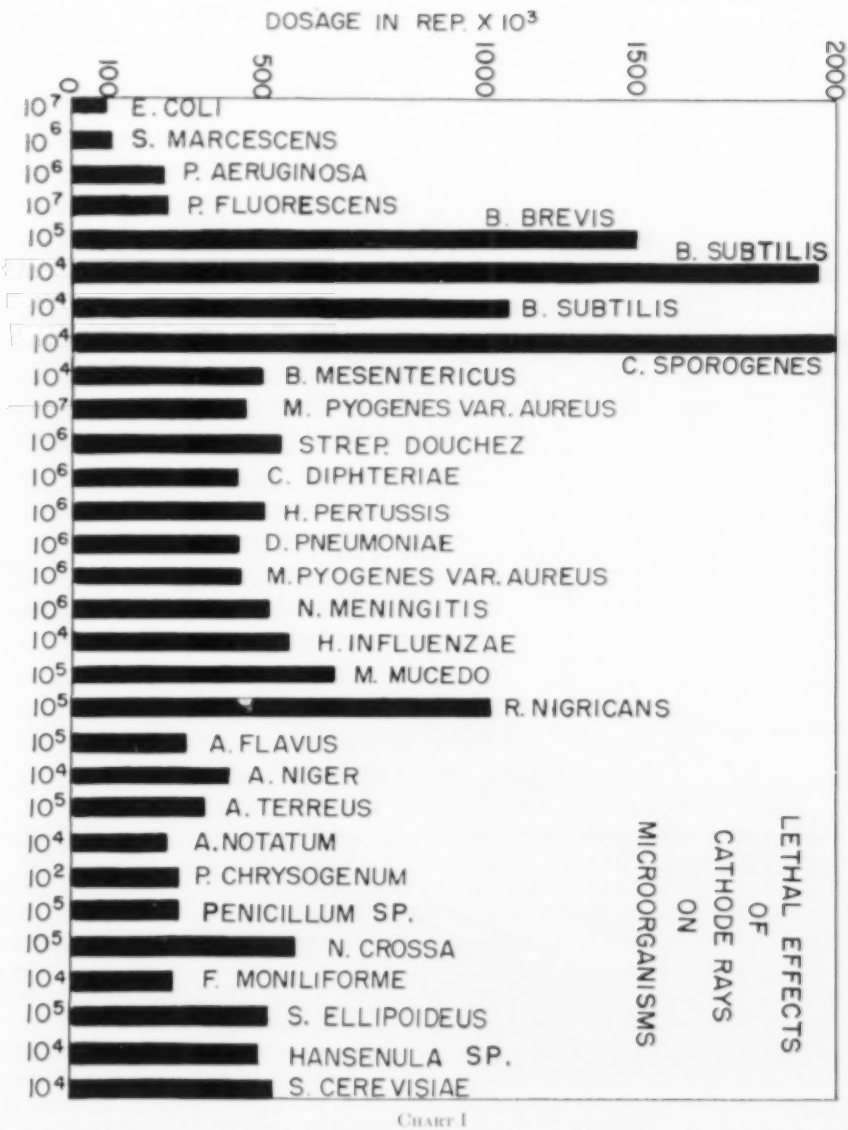

CHART I

This chart (reproduced by permission of J. H. Moriarty, Department of Food Technology, Massachusetts Institute of Technology) shows the lethal doses of high-voltage cathode rays for various micro-organisms suspended in suitable media and irradiated at room temperature. Doses are expressed in roentgen equivalent physicals.

TABLE I

NUMBER OF VIABLE *Staphylococcus aureus* RECOVERED FROM IRRADIATED AND CONTROL BONE SAMPLES STORED IN DRY ICE.

Sample No.	REP × 10^{-3}	Hours Storage over Dry Ice	Average Control Count per Bone Sample	Number of Viable Organisms per Bone Sample	Per cent Destroyed
1A	500	44	3.22×10^{6}	7	99.9998
2A	500	44	3.22×10^{6}	23	99.9993
3A	500	44	3.22×10^{6}	17	99.9995
4A	500	44	3.22×10^{6}	13	99.9997
5A	1000	67	1.46×10^{7}	0	100
6A	1000	67	1.46×10^{7}	0	100
7A	1000	67	1.46×10^{7}	0	100
8A	1000	67	1.46×10^{7}	0	100
9A	1000	71	6.75×10^{5}	0	100
10A	2000	71	6.75×10^{5}	0	100
11A	2000	71	6.75×10^{5}	0	100
12A	2000	71	6.75×10^{5}	0	100
13A	2000	91	4.74×10^{5}	0	100
14A	2000	91	4.74×10^{5}	0	100
15A	4000	91	4.74×10^{5}	0	100
16A	4000	91	4.74×10^{5}	0	100
17A	4000	95	3.71×10^{5}	0	100
18A	4000	95	3.71×10^{5}	0	100
19A	4000	95	3.71×10^{5}	0	100
20A	6000	95	3.71×10^{5}	6	100
21A	6000	115	2.82×10^{5}	0	100
22A	6000	115	2.82×10^{5}	0	100
23A	6000	115	2.82×10^{5}	0	100
24A	6000	115	2.82×10^{5}	0	100
25A	8000	120	2.96×10^{5}	0	100
26A	8000	120	2.96×10^{5}	0	100
27A	8000	120	2.96×10^{5}	0	100
28A	8000	120	2.96×10^{5}	0	100
29A	8000	140	2.55×10^{5}	0	100
30A	10000	140	*	0	100

* No control bone samples

forming the irradiation at low temperatures, as was demonstrated by Meeker and Gross in the irradiation of arterial grafts.

In a detailed study Moriarty [8,9] determined that the lethal dose should be theoretically slightly higher in the frozen state than that at room temperature. This would occur because secondary irradiation will not affect "free water" at dry-ice temperatures. Because of this effect of irradiation on water, organisms suspended in water and in saline would require less irradiation at killing doses than if they were suspended in broth or protein solutions. In this experiment, irradiation was accomplished at dry-ice temperatures in order to minimize the possible destructive changes in bone similar to those found in arterial grafts irradiated at room temperatures by Meeker and Gross.

The advantage of cathode rays over x-rays or other sources of ionizing radiation as a sterilizing agent for biological materials is primarily due to the high inherent efficiency and the accuracy of control of the cathode-ray dose [11]. For many biological materials this factor outweighs the disadvantage of the relatively low penetration of cathode rays as compared with that of x-rays.

Determination of the practicality of bone-graft sterilization by cathode irradiation

TABLE II

NUMBER OF VIABLE *S. aureus* RECOVERED FROM FREEZE-DRIED, IRRADIATED AND CONTROL BONE SAMPLES

Sample No.	REP $\times 10^{-4}$	Average Control Count Per Bone Sample	Number of Viable Organisms Per Bone Sample	Per cent Destroyed
1	500	1.65×10^{6}	47	99.99997
2	500	1.65×10^{6}	54	99.99997
3	500	1.65×10^{6}	71	99.99996
4	500	1.65×10^{6}	10	99.99999
5	1000	2.61×10^{6}	0	0
6	1000	2.61×10^{6}	0	0
7	1000	2.61×10^{6}	0	0
8	1000	2.61×10^{6}	0	0
9	1500	2.08×10^{5}	0	0
10	1500	2.08×10^{6}	0	0
11	1500	2.08×10^{6}	0	0
12	1500	2.08×10^{6}	0	0
13	2000	1.77×10^{6}	0	0
14	2000	1.77×10^{6}	0	0
15	2000	1.77×10^{6}	0	0
16	2000	1.77×10^{6}	0	0

NOTE: None of the irradiated or control lyophilized bone specimens were under vacuum when received. Although the average control counts for each sampling group are fairly uniform the individual counts for each specimen varied from 6.3×10^{5} to 4.59×10^{6}. This is most probably due to the fact that the dog rib specimens did not homogenize as readily and uniformly in the Waring Blendor as the previous samples of rabbit iliac specimens.

involved three initial problems: (1) the dose of cathode irradiation that sterilizes bone; (2) whether such a dose is detrimental to subsequent graft healing; and (3) the determination of the influence of the method of preservation on sterilization dose requirements and on subsequent graft healing. In the evaluation of these problems the experiment was performed in two parts: determination of the sterilizing dose for bones and determination of the effects of irradiation on bone-graft healing in the experimental animal.

DETERMINATION OF STERILIZING DOSES

Uniform sections of frozen and freeze-dried grafts were injected with equal quantities

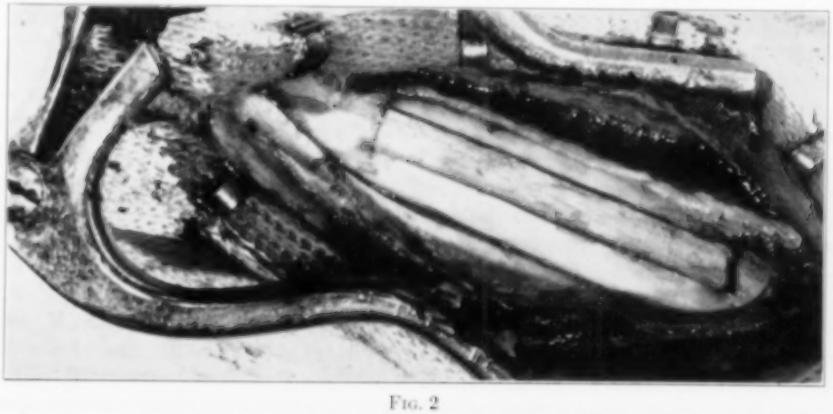

FIG. 2

The operative procedure for evaluating the effect of cathode irradiation on bone-graft healing consisted in implanting bilateral cortical inlay grafts in the radii of adult mongrel dogs. Sterile irradiated freeze-dried grafts were implanted on the right with freeze-dried non-irradiated controls, stored for an equal period of time, on the left in one series of dogs. Another group of dogs received frozen irradiated and control grafts.

TABLE III

Dog No. OC series	Dosage of irradiation REP (million)	Period of implantation in days	Storage time of grafts in days	Position of graft (poor-good)	Reactive new bone (0-++++)	Remodeling (0-++++)	Revascularization (0-++++)
21L	1/2	35	95	F	3	0	0-1
21R				F-P	3-4	0	0-1
8L	1/2	90	50	G	1	2-3	1-2
8R				G	2	2	1
29L	1/2	90	106	G	0-1	3-4	1-2
29R				G	0-1	3-4	1-2
42L	1/2	93	27	G	0-1	3	0-1
42R				G	0-1	3	0-1
24L	1	36	92	G	3	0	0-1
24R				G	4	0	1-2
9L	1	90	57	P	2-3	2	2
9R				G	3-4	0	3
30L	1	90	106	G	1	3	1-2
30R				G	1	3	1-2
43L	1	90	29	F-G	0-1	3	0-1
43R				F	1	3	1
10L	2	90	57	F	2	1-2	1-2
10R				G-F	2-3	2-3	2-3
45L	2	90	55	G	0	3-4	1-2
45R				G	0-1	3	2
26L	4	35	61	G	3	0-1	1
26R				G	3-4	0-1	0-1

Tables III and IV: These tables contain the numerical values (from *0* to *4*) given the various aspects of graft healing in addition to other related data of importance in determining the final estimation of whether the frozen irradiated grafts (designated *R* for right radius after each dog number) or their controls (labeled *L* for left radius) healed more rapidly. The stages of healing used here were: *1*, reactive new-bone formation; *2*, revascularization; *3*, perivascular new-bone formation; and *4*, appositional bone growth. Graft position in relation to the host bone was designated good (G), fair (F), or poor (P). One graft (OC22R) was so poorly positioned that it could not be evaluated. Two animals were not used because of premature death due to pneumonia (OC31) and encephalitis (OC44). Graft OC28R was included in the evaluation, but the reliability of the evaluation is questionable because of the existence of a wound infection which may have altered revascularization and replacement. Staining differential signifies the degree of basophilia of grafts as compared with host bone; this increased bluish discoloration was roughly proportional to the dose of cathode rays. Abnormal absorption of fragmentation was present in some of the irradiated grafts as indicated.

of a standard bacterial strain. The sterilizing dose for this organism and for a rather wide spectrum of other bacteria in pure culture had been previously determined by Moriarty (Chart I). More complete studies with different strains of organisms could be accomplished later if the results of this experiment warranted them. *Staphylococcus aureus* (F.D.A. 209 strain) was used in this study. Lethal-dose studies were carried out in frozen and freeze-dried grafts in order to determine whether the state of preservation influenced the dose levels.

Determination of Sterilizing Dose for Contaminated Frozen Bone

Thirty-two sections (one centimeter in diameter) of rabbit ilia were obtained by trephine at sterile autopsy. These sections were halved and were inoculated with 0.5 milliliter of beef-heart infusion broth containing 1.33×10^8 viable *Staphylococcus aureus* (F.D.A. 209 strain). Thirty-two inoculated half-sections were stored in glass tubes and were immediately frozen in dry ice and sterilized by cathode irradiation. Their thirty-two similarly inoculated counterparts were kept in dry ice as controls.

TABLE III

Amount of perivascular new bone (0-++++)	Stage of healing 1, 2, 3, 4	Staining differential of graft (0-++++)	Amount of residual graft (0-++++)	Abnormal absorption of graft (0-++++)	Comparative extent of healing: L:R	General host reaction (0-++++)
0-1	1	0	4	0	Same	3
0-1	1	0	4	0		3-4
2-3	3	0	2	0	Same	1-2
2-3	3	0	2	0		1
1-2	2-3	0	3	0	Same	0-1
1	2-3	0	3	0		0-1
1-2	1-2-3	0	3	0	Same	0-1
1-2	1-2-3	0	3	0		0-1
0-1	1	0	4	0	1	2
0-1	1-2	0	3	1		3
1-2	2	0	3	0	1	1
2	2-3	1-2	2	1		1
1-2	2-3	0	3	0	Same	1
1-2	2-3	1	3	0		1
1	1-2-3	0	3-4	0	Same	0-1
1	1-2-3	0	3-4	0		1
3	3	0	3	0	1	1-2
2	3	4	2-3	0		2
1-2	2-3	0	3-4	0	1-2	0-1
2-3	2-3	1	2-3	0-1		0-1
1	1-2	0	3-4	0	0-1	3
1	1-2	1-2	4	0		3

Doses of 0.5 to 10.0 million roentgen equivalent physicals were used to irradiate the initial thirty-two half-sections at dry-ice temperature (−78 degrees centigrade). In order to maintain identical conditions of storage and transit in both groups, the control specimens and the specimens for irradiation were shipped simultaneously to the Massachusetts Institute of Technology. All specimens were returned to the Bacteriological Laboratory of the Naval Medical Research Institute and were cultured quantitatively. Specimens were individually homogenized with saline for one minute in a Waring Blendor before the preparation of a tryptone glucose extract agar pour plate. Serial dilutions were made in the preparation of control specimens. The entire homogenized specimen was plated and the number of viable organisms was determined in each irradiated specimen. All plates were read with a Quebec Colony Counter after forty-eight hours of incubation at 37 degrees centigrade. The counts were expressed as the total number of organisms recovered from each specimen. Table I demonstrates that at a dose of 0.5 million roentgen equivalent physicals, 99.9997 per cent of the organisms were destroyed. At 1.0 million roentgen equivalent physicals, complete sterilization was accomplished.

The effect of storage at dry-ice temperature was similarly investigated. Before freeze-drying, twelve sections of bone were inoculated with 1.33×10^8 organisms of the standard strain. After freezing for thirty minutes at dry-ice temperatures (−78 degrees centigrade), 3.66×10^6 organisms were noted in each of four sections; after ten hours at dry-ice temperatures, 3.21×10^6 organisms were found in each of the four frozen sections; finally, after ninety hours at this temperature, 3.12×10^6 organisms were counted. Although the initial freezing of the bone specimens caused a pronounced drop in the number of organisms, a sufficiently large number remained over a period of time to render the kill end-points valid.

TABLE IV

Dog No. OC series	Dosage of irradiation REP (million)	Period of implantation in days	Storage time of grafts in days	Position of graft (poor-good)	Reactive new bone (0-++++)	Remodeling (0-++++)	Revascularization (0-++++)
40L	4	31	26	G	2-3	0-1	0-1
40R				G	1-2	2	0
11L	4	90	31	G	1	2-3	2-3
11R				G	1	2-3	3
46L	4	90	55	G	0	3	1-2
46R				G	1-2	1-2	2-3
28L	6	35	70	G	1	3	0-1
28R				F-P	3	0	2-3
12L	6	91	38	G	2	1-2	1
12R				G	1	3-4	3
41L	6	90	26	F	1	3	1-2
41R				G	1-2	2-3	3
Omitted							
22L	2	35	90	G	2	2	0-1
22R	Omit				3	1	1
31L	2	16	120	G	2	0	0
31R				G	2	0	0
44L	2	28	29	F	1-2	0	0
44R				G	1	0	0

Determination of Sterilizing Dose for Contaminated Freeze-Dried Bone

Dog rib has approximately the same density and thickness as rabbit ilium; therefore, thirty-two uniform one-centimeter specimens of rib were inoculated with the same quantity of the standard strain as was used previously. (The use of rabbits was discontinued after discovering that the grafting procedure was unsatisfactory because of fracture of the ilium around the graft.) The bone sections were stored in sterile glass containers and were freeze-dried immediately after inoculation [3]. The previously reported method of freeze-drying has been altered in that we no longer consider it necessary to coat the bone with a shell of ice [4]. The material in this experiment (like the human bone now in use clinically) was placed in the vacuum chamber of the freeze-drier in the frozen state without the previously described ice-coating. The freeze-dried specimens were then sealed in glass tubes, were stored in dry ice, were transported to the irradiation laboratory where one-half were irradiated at this temperature in the same manner as were the frozen grafts previously described. The irradiated and control materials were returned to our laboratory and were quantitatively cultured as previously described. The results in Table II indicate complete sterilization at a dose of 1.0 million roentgen equivalent physicals and 99.999 per cent destruction of bacteria at 0.5 million roentgen equivalent physicals.

Sterilizing Doses for Various Micro-Organisms

The reported results (Table II) indicate that a dose of 0.5 million roentgen equivalent physicals causes almost complete sterilization, and 1.0 million roentgen equivalent physicals ensured complete sterilization of bone in both the frozen and freeze-dried specimens. The same strain of organism, suspended in nutrient broth, was completely destroyed at slightly less than 0.5 million roentgen equivalent physicals (Chart I). As stated previously, this difference may be due to the variation in temperature of irradiation or to the difference in protective action of the protein suspension medium used by Moriarty as

TABLE IV

Amount of perivascular new bone (0–++++)	Stage of healing (1, 2, 3, 4)	Staining differential of graft (0–++++)	Amount of residual graft (0–++++)	Abnormal absorption of graft (0–++++)	Comparative extent of healing L:R	General host reaction (0–++++)
1	1	0	4	0	Same	1
0	1	0	4	0		1-2
1-2	2-3	0	2-3	0	1	0-1
3	3-4	0	1-2	0		1
1-2	2-3	0	3-4	0	1	0-1
1-2	2-3	3-4	2-3	0-1		1
0-1	1-2	0	4	0	2(?)*	0-1
1-2	2-3	2-3	2-3	1		1-2
1	1-2	0	3-4	0	1-2	2
3	2-3-4	3	1-2	1		2
1-2	2-3	0	2-3	0	1	0-1
2-3	2-3	4	1-2	1-2		0-1
0	1	0	4	0	?	1
1	1-2	0	3-4	0		3
0	1 early	0	4	0	Same	1
0	1 early	0	4	0		1
0-1	1	0	4	0	Same	1
0	1	0	4	0		1

compared with that of bone. However, this difference is so small that approximate lethal doses for other organisms in bone may conceivably be calculated by using the broad spectrum given in Chart I. Nevertheless, extensive determinations of sterilizing doses for specimens of various sizes of human bone contaminated with numerous different organisms should be carried out before irradiated bone is used clinically.

In order to increase this lethal-dose spectrum for commonly encountered microorganisms, Dunn, Moriarty (Massachusetts Institute of Technology), and Olson (National Institutes of Health) irradiated several different organisms at our request. The following were sterilized in pure culture suspended in suitable media:

1. *Salmonella typhimurium:* slightly less than 500,000 roentgen equivalent physicals;
2. *Brucella abortis:* less than 500,000 roentgen equivalent physicals;
3. *Clostridium perfringens:* 1 million roentgen equivalent physicals;
4. *Mycobacterium tuberculosis:* between 250,000 and 500,000 roentgen equivalent physicals.

EFFECTS OF CATHODE IRRADIATION ON BONE-GRAFT HEALING

Having obtained a rough theoretical determination of the sterilizing dose of cathode rays for small sections of bone, it remained to determine whether this amount of irradiation impaired bone healing and whether the method of preservation had any influence on graft healing after irradiation. In order to accomplish this, bilateral homogenous cortical inlay grafts were implanted into the radii of adult dogs using the technique previously employed in this laboratory and reported by Kreuz and his associates. In order to determine the influence of the method of preservation on graft healing of irradiated bone, two series of implantations were carried out; frozen irradiated and control grafts were used in one group of animals and freeze-dried irradiated and controls were used in the other.

TABLE V

Dog No. OC Series	Dosage of irradiation REP (million)	Period of implantation in days	Storage time of grafts in days	Position of graft (poor-good)	Reactive new bone (0-++++)	Remodeling (0-++++)	Revascularization (0-++++)
20L	1/2	35	101	F	3	1	1-2
20R				F	3	1	1-2
35L	1/2	35	143	G-F	3-4	0-1	1
35R				G	3	0	1
3L	1/2	91	44	G	1	2-3	2-3
3R				G	1-2	2-3	4
37L	1/2	90	150	G	0-1	3-4	3-4
37R				F-G	1-2	2-3	3
34L	1	35	143	P	1-2	2	2
34R				F	3	1	3-4
6L	1	91	56	G	2-3	1-2	2
6R				G	1	3	2-3
19L	1	90	100	G-F	2	2	3
19R				P	2-3	2-3	3-4
36L	1	90	150	G	1	3	3
36R				G	2	2	3-4
5L	2	90	53	G	1-2	2	3
5R				G	1-2	2	2-3
13L	2	90	88	P	4	0	3-4
13R				G	3	2-3	3-4
32L	2	90	143	F-P	2	3	3-4
32R				P	2	3	2

Tables V, VI, and VII: These are the evaluation tables for freeze-dried irradiated and control grafts. The method of evaluation is similar to that described for the frozen graft series in Tables III and IV. Three dogs were not used because of death due to dog fight (OC1) or pneumonia (OC14 and OC17). Another was omitted because of very poor fitting graft (OC23) on one side, and in another (OC18R) the graft was too fragmented for satisfactory comparison.

Method of Graft Procurement, Treatment, and Storage

On several occasions large numbers of uniform homogenous grafts were procured at sterile autopsy from dogs. These were divided into two groups. All grafts in each group were stored in identical fashion, frozen or freeze-dried. One-half of the grafts were freeze-dried in a commercial freeze-drying machine for approximately two weeks [3]. After processing, they were stored in individual vacuum-sealed glass ampules. One-half of each group of freeze-dried grafts were retained as controls; the others were irradiated at dry-ice temperatures at doses of 0.5, 1.0, 2.0, 4.0 and 6.0 million roentgen equivalent physicals. Irradiated freeze-dried grafts and their freeze-dried controls were stored at room temperature for future implantation. This method of storage in vacuum-sealed ampules is a definite improvement over the previously reported technique [4]. Freeze-dried grafts stored in a vacuum maintain a minimum moisture content and undergo minimum oxidation during storage.

The frozen grafts were stored individually in rubber-stoppered test tubes at −78 degrees centigrade. This low temperature was used because others have found that this lower storage temperature resulted in better preservation of arterial grafts than those stored in the average deep freeze at −15 degrees centigrade to −30 degrees centigrade [1,2]. Theoretically the same may be true for bone.

It was originally planned to have identical storage times for all frozen and freeze-

TABLE V

Amount of perivascular new bone (0-++++)	Stage of healing 1, 2, 3, 4	Staining differential of graft (0-++++)	Amount of residual graft (0-++++)	Abnormal absorption of graft (0-++++)	Comparative extent of healing L:R	General host reaction (0-++++)
1	2	0	3-4	0	Same	2
2	2-3	0	3-4	0		2
1-2	1-2-3	0	3	0	Same	2-3
1	1-2	1	3	0		1
2	2-3	0	2	0	0-1	1-2
3	2-3	2	1	3		1-2
3-4	2-4	0	0-1	0	1	0-1
3	2-3	0	0-1	0		1
2	2-3	0	2-3	0	Same	1
1	2	3	2	3		2
2-3	2	0	2	0	0-1	1
2	2-3	0-1	2	0		1
2-3	2-3	0	2	0	Same	2
2-3	2-3	0-1(?)	1-2	0		2
3-4	2-3	0	0-1	0	Same	1
3-4	2-3	0	0-1	0		1-2
2	2-3	0	1-2	0	1	1-2
2	2-3	2	2	1(?)		1
3	2-3	0	1	0	1	4
4	2-3	0-1	0-1	0		3
3	2-3	0	0-1	0	1-2	1
2	2-3	1	2	1		1

dried grafts, but technical difficulties made it impossible to keep the frozen grafts at −78 degrees centigrade continuously for the duration of the experiment. Therefore, new groups were procured on two occasions. This resulted in longer storage times for the freeze-dried grafts. However, in both groups the irradiated and control grafts in each animal had equal storage periods.

One-half of each group of frozen grafts were irradiated at −78 degrees centigrade.

Implantation of Bone

Bilateral cortical inlay grafts in the radii of adult mongrel dogs were used for this study (Fig. 2). This type of rectangular graft measuring approximately 0.5 by 4.0 centimeters remains in position without the use of additional fixation. This offers the maximum amount of contact between the graft and host bone. Uncontaminated grafts irradiated at doses of 0.5 to 6 million roentgen equivalent physicals were implanted into the right radii; the uncontaminated control grafts were implanted in the left. In each animal, the control graft was approximately the same size and had been stored under similar conditions for the same period of time as the irradiated graft. Therefore, the only variable was the irradiation.

In previous experiments, it was found that the optimum period for observing initial and maximum bone revascularization was respectively thirty-five to ninety days after implantation [4]. Therefore, all animals were sacrificed and were brought to autopsy at thirty-five or ninety days. In a total of forty-seven dogs bilateral grafting procedures were carried out. Of these, six died (three from pneumonia, one from encephalitis, one as a result of anaesthesia, and one as a result of a dog fight), and three were discarded because of an unsatisfactory operative technique. There remained thirty-eight dogs, twenty-one

TABLE VI

Dog No. OC series	Dosage of irradiation REP (million)	Period of implantation in days	Storage time of grafts in days	Position of graft (poor-good)	Reactive new bone (0-++++)	Remodeling (0-++++)	Revascularization (0-++++)
25L	4	35	108	G	2	1	1
25R				F-P	3-4	0	0-1
39L	4	35	158	F-G	2	2	1
39R				VP	3	0-1	0-1
4L	4	90	45	F	2-3	2	2
4R				F-P	2	2-3	2
7L	4	90	64	F	1-2	2	4
7R				F-G	4	0-1	2
16L	4	92	91	G	1	3	2
16R				F	1-2	2	1-2
27L	6	35	115	P	4	0-1	1-2
27R				F-P	4	0-1	1
38L	6	42	158	VP	4	0-1	0-1
38R				F-P	3	0-1	1
2L	6	90	39	G	1	3	3-4
2R				G	1-2	3	3
15L	6	92	91	G-F	1	3	4
15R					3	1	2-3
33L	6	90	143	G	1-2	3	3
33R				G-F	2-3	1	3-4

TABLE VII

Dog No. OC series	Dosage of irradiation REP (million)	Period of implantation in days	Storage time of grafts in days	Position of graft (poor-good)	Reactive new bone (0-++++)	Remodeling (0-++++)	Revascularization (0-++++)
17L	1/2	23 1/2	93	G	4	0	0-1
17R				F	3-4	0	0-1
14L	1	34 1/2	88	F-P	3	0	1-2
14R				F-P	2-3	0-1	1
23L	1 Omit	35	108	G	1-2	3	2
23R				P	2	1-2	0
1L	2	15		G	0-1	0	0
1R				G	0-1	0	0
18L	2	35	93	G	4	0	0
18R				F	3	0	?

in which the freeze-dried grafts had been used and seventeen in which the frozen grafts had been used.

Method of Interpretation

At the time of autopsy, roentgenograms were made of the entire foreleg in order to locate the graft accurately. By superimposing the roentgenogram on the radius, a 0.5 to 1.0 centimeter transverse section was taken from the middle area of the graft. These sections of bone were fixed in buffered formalin solution and electrolytically decalcified. Sections ten micra thick, stained with hematoxylin and eosin, were prepared.

TABLE VI

Amount of perivascular new bone (0-++++)	Stage of healing 1, 2, 3, 4	Staining differential of graft (0-++++)	Amount of residual graft (0-++++)	Abnormal absorption of graft (0-++++)	Comparative extent of healing L:R	General host reaction (0-++++)
1	2-3	0	3-4	0	1	2
0	1-2	1-2	4	0		3
0-1	1-2	0	3-4	0	0-1	1
0	1	1	4	0		3
2	2-3	0	1-2	0	0-1	2
2	2-3	1	1-2	1		1-2
?	2(?)	2	1	2	2	2
0-1	2(?)	2	2-3	0		2
2-3	2-3	0	3	0	1-2	1
1-2	1-2-3	2	3	1		1
1	1-2	0	3-4	0	1	2-3
0-1	1-2	2	4	0		2-3
0-1	1	1	3-4	0	0-1	2
0-1	1	1-2	3-4	0		2
2-3	3-4	0	0-1	0	1	2
2	3	4	1-2	2		2-3
3-4	2-3-4	0	0-1	0	2-3	2
1-2	1-2-3	4	2	1		3
2	2-3	0	2	0	1	1
3	2-3	4	1	1		2

TABLE VII

Amount of perivascular new bone (0-++++)	Stage of healing 1, 2, 3, 4	Staining differential of graft (0-++++)	Amount of residual graft (0-++++)	Abnormal absorption of graft (0-++++)	Comparative extent of healing L:R	General host reaction (0-++++)
	1	0	4	0	Same	1
	1	0	4	0		1
1	1-2	0	3-4	0	1	3
0-1	1-2	1-2	3-4	0		3
1	2-3	0	3	0	2	1-2
1	2-3	0	3-4	0		1-2
0	1 early	0	4	0	Same	0-1
0	1 early	0	4	0		0-1
0	2	0	4	0	?	1
?	?	?	0-1	4		1

In the comparison of the irradiated with the control grafts from each animal, an attempt was made to assign numerical values from 0 through 4 to each of the various factors or aspects of graft healing as shown in Tables III, IV, V, VI, and VII. It was difficult in some sections to determine exactly how much of the graft remained, merely on the basis of the presence or absence of osteocytes in the lacunae of the graft area; this was especially true in the controls and the frozen grafts. This problem usually did not exist in the irradiated grafts because of the increased staining of the basophilic matrix, probably the result of irradiation.

In the rough classification of the stage of healing we used numerical values as fol-

TABLE VIII

COMPARISON OF HEALING OF IRRADIATED AND CONTROL GRAFTS

FREEZE-DRIED

Dosage in Million rep	Dog OC Number	H. A.* 35 days	Dog OC Number	H. A.* 90 days
½	20	0	3	control +
	35	0	37	control +
1	34	0	6	irradiated 0 + 0 +
			19	0
			36	0
2			13	irradiated +
			5	control +
			32	control + +
4	25	irradiated +	4	control +
	39	0	7	control + +
			16	control + to + +
6	38	irradiated 0 to +	33	irradiated +
	27	control +	2	control +
			15	control + + to + + +

FROZEN

Dosage in Million rep	Dog OC Number	H. A.* 35 days	Dog OC Number	H. A.* 90 days
½	21	0	8	0
			29	0
			42	0
1	24	irradiated +	30	0
			43	0
			9	irradiated +
2			10	irradiated +
			45	irradiated + to + +
4	40	0	11	irradiated +
	26	control 0 to +	46	irradiated +
6	28	irradiated + + (?) (wound infection)	12	irradiated + to + +
			41	irradiated +

* H. A. = Healing advantage

This table is a summary of the previous evaluation tables (Tables III through VII). The results indicate that a sterilizing dose of 1 million rep probably causes little if any impairment in graft healing whether the grafts are frozen or freeze-dried. Doses over 2 million rep seem to cause some retardation of freeze-dried graft healing while the frozen grafts appear to heal more rapidly at these high doses. However, as stated in the text, the over-all superiority of freeze-dried graft healing over frozen grafts probably outweighs this apparent beneficial effect of irradiation on frozen grafts.

lows: *1*, reactive new-bone formation; *2*, revascularization; *3*, perivascular new-bone formation; and *4*, appositional bone growth. In some of the animals there was variation in the final positioning of the grafts between the control and the irradiated as indicated

TABLE IX

35-Day Grafts

Dosage in rep	Average Amount of Residual Graft (4 = Entire Original Graft)		Dosage in rep	Average Amount of Graft Replaced (= 4 Minus Residual Graft)	
	Freeze-dried	Frozen		Freeze-dried	Frozen
½	3½ (1 graft)	4 (1 graft)	½	½	0
1	2 (1 graft)	3 (1 graft)	1	2	1
2	No graft	No graft	2	–	–
4	4 (2 grafts)	4 (2 grafts)	4	0	0
6	4 (2 grafts)	2½(?)* (1 graft)	6	0	1½(?)*
Non-irradiated control grafts	3⅕ (5 grafts)	3⅗ (5 grafts)	Non-irradiated control grafts	⅘	⅖

* This leg (OC28R) had a wound infection which may have accelerated revascularization and replacement of the graft.

99-Day Grafts

Dosage in rep	Average Amount of Residual Graft (4 = Entire Original Graft)		Dosage in rep	Average Amount of Graft Replaced (= 4 Minus Residual Graft)	
	Freeze-dried	Frozen		Freeze-dried	Frozen
½	¾ (2 grafts)	2⅔ (3 grafts)	½	3¼	1⅓
1	1⅗ (3 grafts)	2⅝ (3 grafts)	1	2⅔	1⅜
3	1⅙ (3 grafts)	2½ (2 grafts)	2	2⅝	1½
4	2⅓ (3 grafts)	2¼ (2 grafts)	4	1⅔	1¾
6	1½ (3 grafts)	1⅔ (2 grafts)	6	2½	2⅓
Non-irradiated control grafts	1³⁄₁₀ (10 grafts)	2¹⁹⁄₂₀ (10 grafts)	Non-irradiated control grafts	2⁷⁄₁₀	1¹⁄₂₀

The amount of residual graft is probably the best index of the rate of healing of bone grafts. Thus the less residual graft, the more advanced the healing. These figures are taken from the tables in Tables III through VII. The results indicate slight retardation of healing of the freeze-dried grafts at higher doses, while the frozen grafts seemed to heal more rapidly at these higher dose levels. However, the freeze-dried grafts still seem to be equal to or slightly superior to frozen grafts at high doses. This superiority of freeze-dried grafts is rather marked at the lower sterilizing dose levels and in the non-irradiated control grafts.

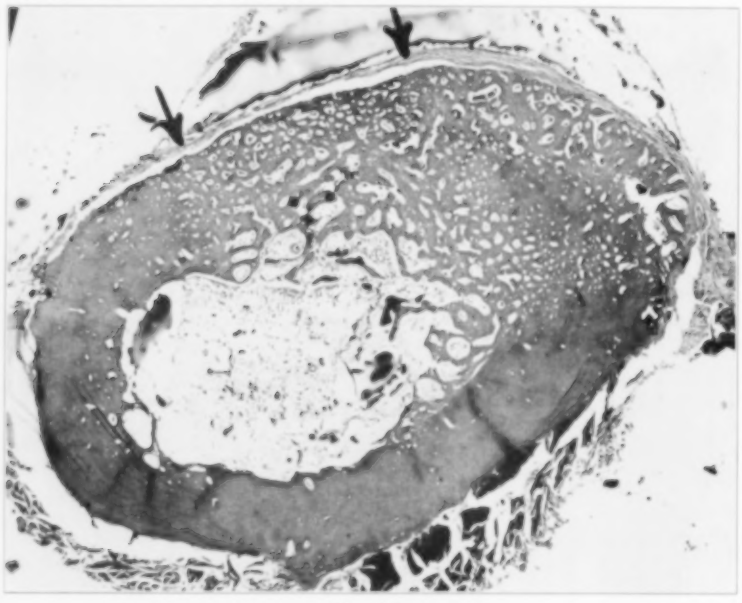

FIG. 3-A

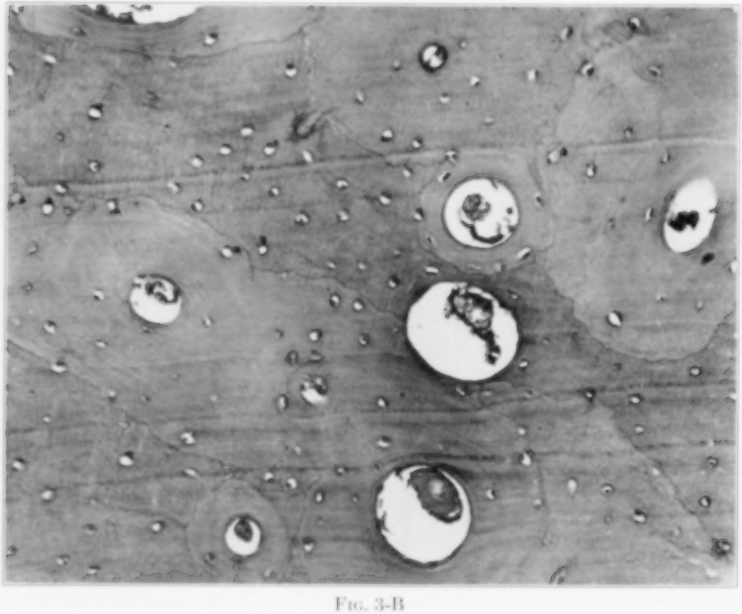

FIG. 3-B

Photomicrographs of a 0.5 million roentgen equivalent physicals freeze-dried irradiated graft (OC37R) ninety days after implantation reveal advanced revascularization and perivascular new-bone formation. At low magnification (× 8, Fig. 3-A), the graft margin is distinct, but at higher magnification (× 125, Fig. 3-B) there are still areas of dead graft as demonstrated by absence of cells in the lacunae. The graft lies between the arrows in the low-power photomicrograph. The control graft in this animal was slightly more advanced than the irradiated. This was also true of the other ninety-day grafts at this dose level. However, the two thirty-five day dogs at 0.5 million roentgen equivalent physicals and all four dogs in the 1 million roentgen equivalent physicals freeze-dried graft group failed to demonstrate any impairment of healing of the irradiated grafts (Table VII).

FIG. 4-A

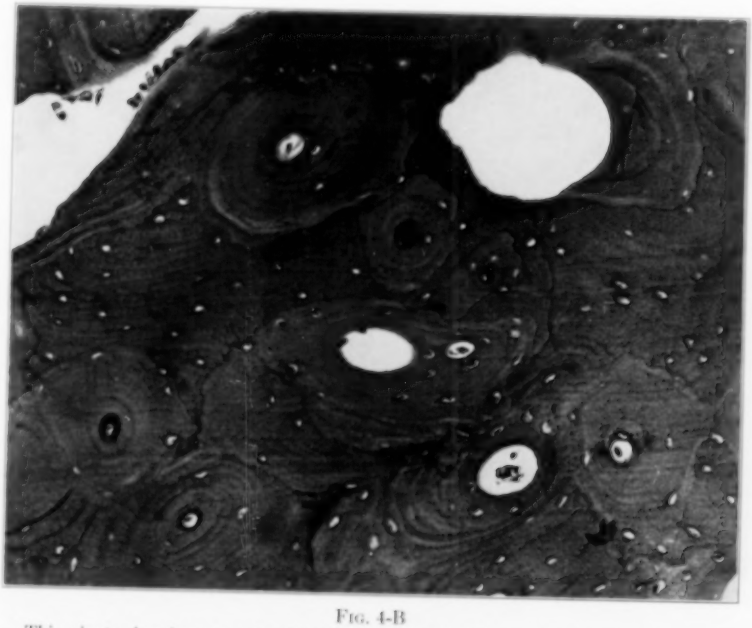

FIG. 4-B

This ninety-day frozen graft (OC29R) was irradiated at a dose level of 0.5 million roentgen equivalent physicals. The graft has been relatively poorly revascularized when compared with a comparable freeze-dried graft (Figs. 3-A and 3-B). In the high-power photomicrograph (× 125) there are large areas of unrevascularized dead graft as determined by absence of cells in the lacunae. This retardation of healing rate of frozen grafts irradiated at low doses and of all non-irradiated frozen grafts was a fairly uniform finding in this experiment (Table IX). There was no detectable difference in healing rate of the frozen irradiated grafts and controls at this dose.

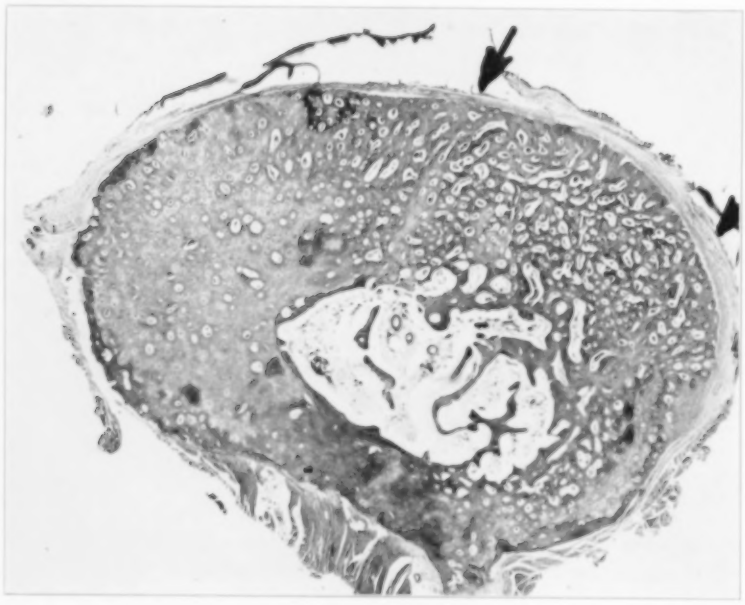

FIG. 5-A

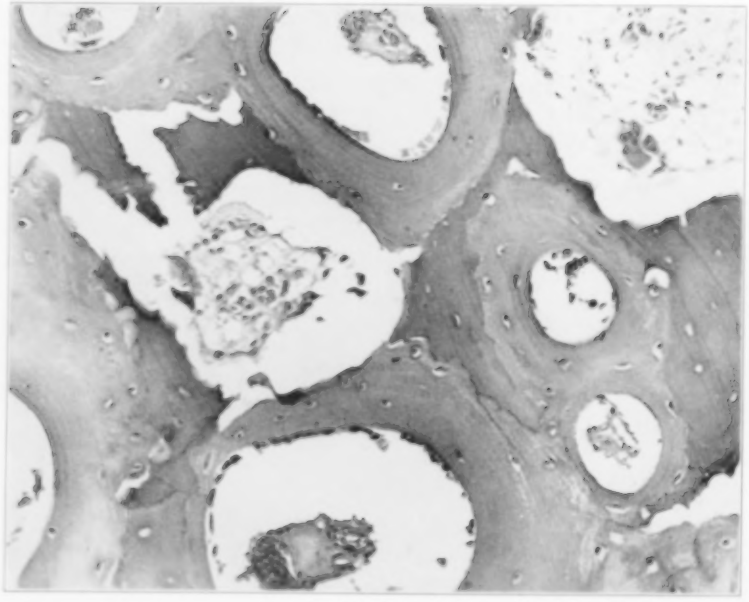

FIG. 5-B

This is a 2 million roentgenogram equivalent physicals freeze-dried irradiated graft at ninety days (0C13R). There is advanced revascularization and perivascular new-bone formation at this dose also making it difficult to distinguish the graft at low magnification (× 8, Fig. 5-A), but in the higher power view (× 125, Fig. 5-B) there is detectable increased basophilia of the relatively small amount of residual graft making its identification easy. The control graft in this dog was not quite as advanced, but in the other two dogs at this dose the reverse was true. Therefore, some significant impairment of freeze-dried graft healing may be caused by a dose of 2 million roentgen equivalent physicals.

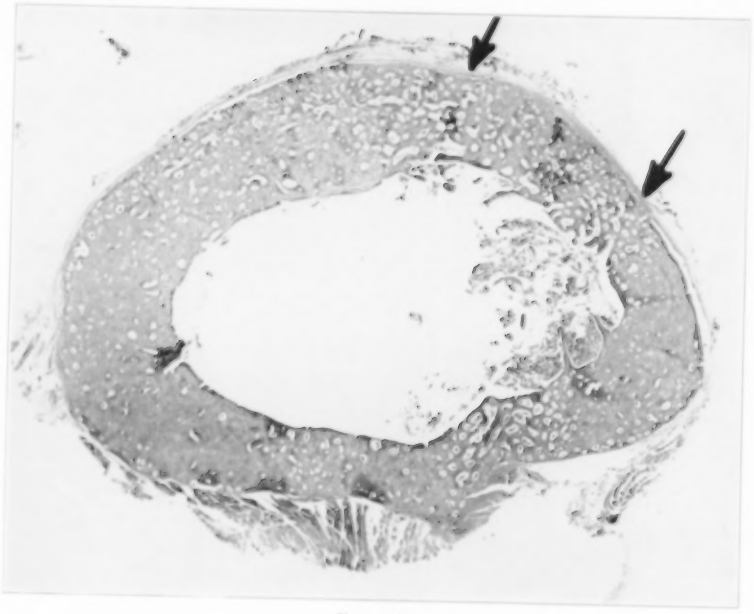

FIG. 6-A

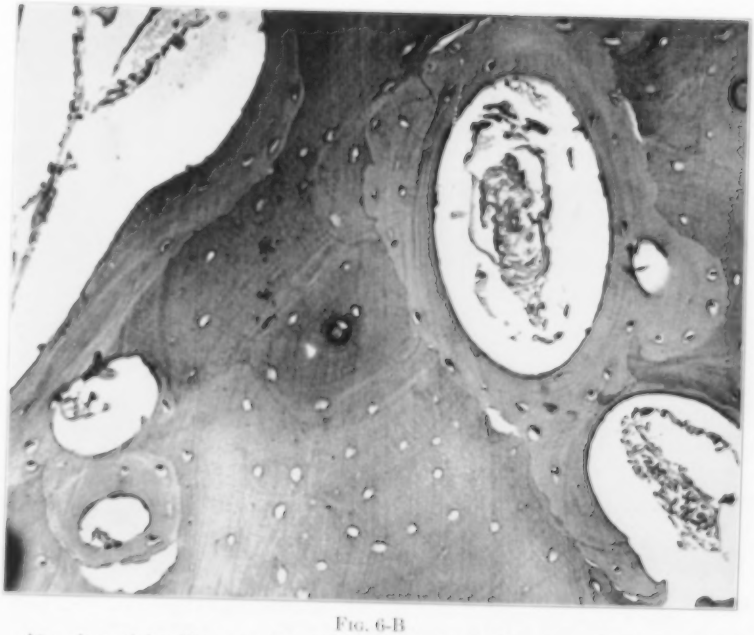

FIG. 6-B

At a dose of 2 million roentgen equivalent physicals this ninety-day frozen graft (OC45R) was more advanced than its control. This was also true of the other graft at this dose (Table VIII). There was slightly more advanced revascularization and perivascular new-bone formation than in the frozen grafts irradiated at 0.5 million roentgen equivalent physicals, but the freeze-dried grafts at 2 million were still ahead (Table IX).

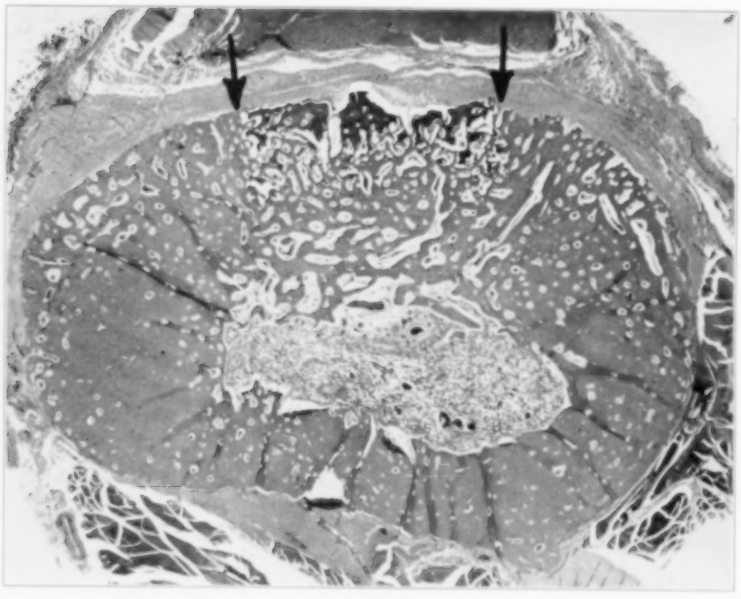

FIG. 7-A

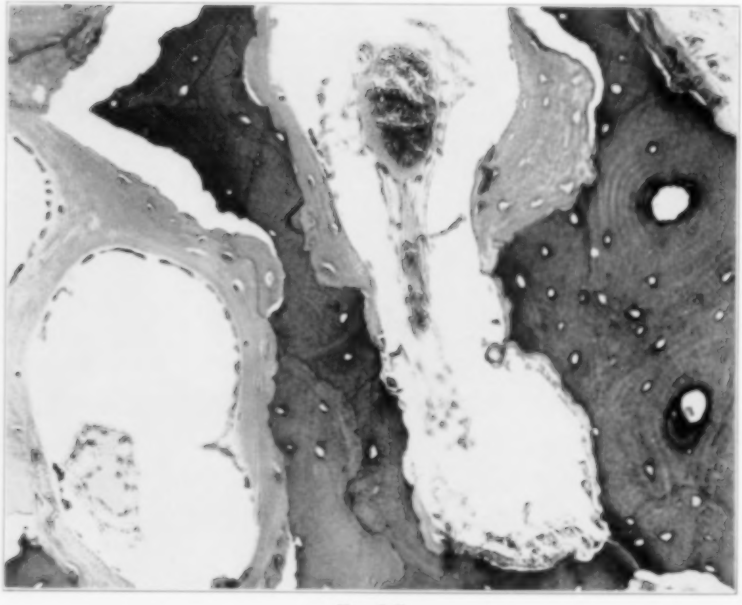

FIG. 7-B

At a dose of 6 million roentgen equivalent physicals this ninety-day freeze-dried graft (OC2R) is clearly visible in the low-power view (× 8, Fig. 7-A) because of marked bluish discoloration. There is also more residual graft (¾ to ½) than there was in the previous grafts (less than ¼) at lower doses. There is some impairment of the cement line in this graft, apparent at high power (× 125, Fig. 7-B) as separation of the graft from the invading new bone. Doses of 4 and 6 million roentgen equivalent physicals caused some impairment of healing in eight out of ten grafts in comparison with their controls.

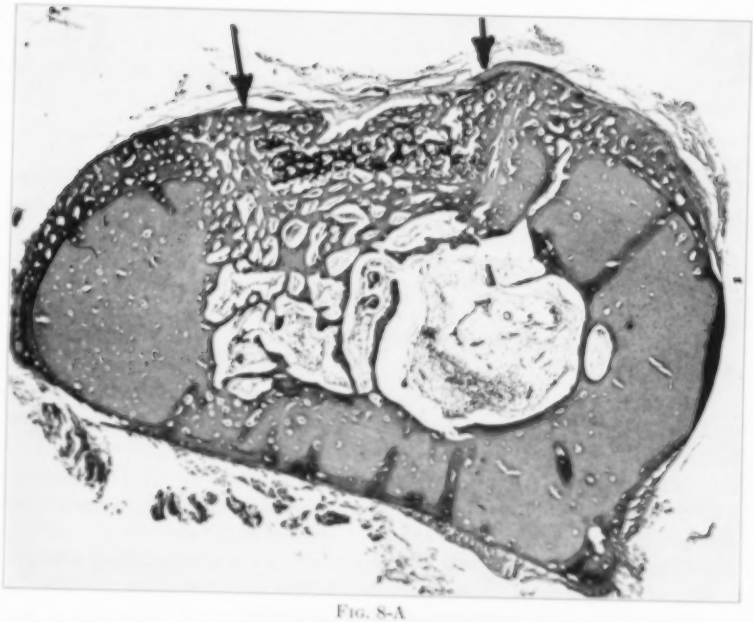

FIG. 8-A

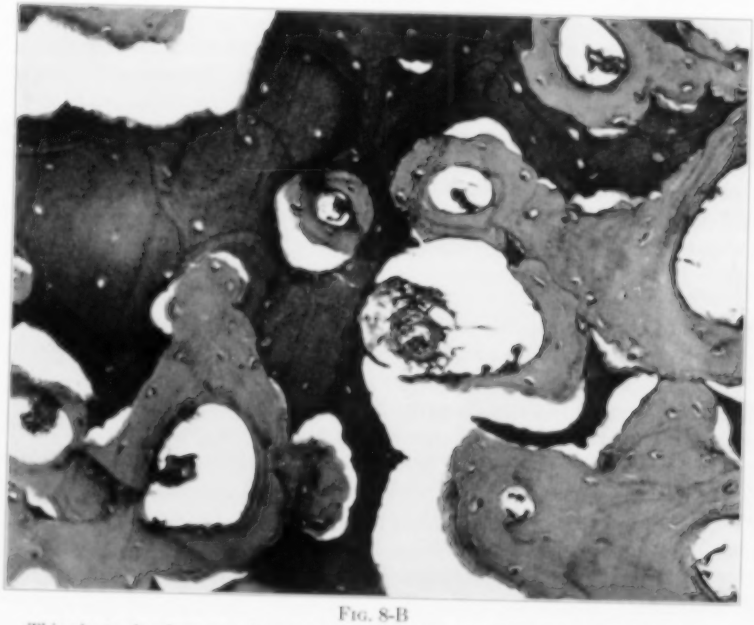

FIG. 8-B

This ninety-day frozen graft was irradiated at 6 million roentgen equivalent physicals. The residual graft is readily identified by the marked degree of bluish discoloration that was also present in the freeze-dried irradiated grafts at this dose. Revascularization of the graft, and perivascular new-bone formation are rather advanced and are at about the same stage found in the 6 million roentgen equivalent physicals freeze-dried grafts (Table IX). Thus, it seems that high-voltage cathode irradiation at higher doses speeds up replacement of the frozen grafts, while it causes some retardation of freeze-dried graft healing. However, at the lower sterilizing doses (1 million roentgen equivalent physicals or less) the freeze-dried grafts are definitely superior to the frozen, whether irradiated or non-irradiated.

in the table. This introduced a variable that must be considered in interpreting the results. Probably the most important factor listed is the amount of residual graft except in those cases in which there was abnormal absorption or fragmentation of some of the irradiated grafts. After consideration of all factors, an estimation of the comparative extent of healing of the controls with that of the irradiated grafts was made. Evaluations of the extent of healing were tabulated from *0* to *4*.

The slides were studied independently by three investigators, who were without knowledge of the type of preservation, amount of irradiation, or postoperative time. There were no gross differences of opinion. A composite of the group interpretation is presented in Tables III, IV, V, VI, and VII. Summaries of the comparative extent of healing of irradiated as against control grafts are presented in Table VIII.

RESULTS

Freeze-Dried Grafts

At a dose of 0.5 million roentgen equivalent physicals there was no detectable impairment of healing of the graft in the two 35-day dogs, whereas there was slight retardation of healing of the graft in the two 90-day irradiated grafts. This suggestion of slight impairment of healing at this low dose is probably discounted by the fact that at 1 million roentgen equivalent physicals no differences were observed in the healing rate of irradiated and control grafts in the group of four dogs (Figs. 3-A and 3-B).

At 2 million roentgen equivalent physicals there is probably mild significant retardation of healing of the irradiated grafts, even though in one of the three animals the healing of the irradiated graft appeared to be slightly more advanced than that of the control (Figs. 5-A and 5-B).

A dose of 4 million roentgen equivalent physicals apparently caused significant impairment of graft healing of mild to moderate degree in all five animals. This trend was not as definite at 6 million roentgen equivalent physicals because in two of the five animals there was slight advancement in healing of the irradiated graft (Figs. 7-A and 7-B).

These results indicate that for freeze-dried grafts, doses below 2 million roentgen equivalent physicals probably cause little if any significant impairment of graft healing while at 2 million roentgen equivalent physicals and above there is some impairment of healing, especially at 4 million roentgen equivalent physicals.

Frozen Grafts

With grafts sterilized at 0.5 million roentgen equivalent physicals there were four animals in which no differences could be detected in the rate of healing of the irradiated over the controls (Figs. 4-A and 4-B).

With grafts sterilized at 1 million roentgen equivalent physicals, two of the four animals demonstrated no significant differences in healing of the grafts, whereas, in the other two, there was slight advancement of healing of the irradiated over the control grafts.

The two animals with grafts sterilized at 2 million roentgen equivalent physicals showed an advancement of healing of the irradiated grafts. In one this was quite distinct, while in the other it was only slight (Figs. 6-A and 6-B).

Grafts sterilized at 4 million roentgen equivalent physicals were inserted in four animals for comparison. In one there was no difference, in two there was slight advancement in healing of the irradiated graft; and in the other there was very slight advancement in healing of the control over the irradiated. This was the lowest dose at which there was an instance of advancement of healing of the control over the irradiated grafts, most of the differences before having been in favor of the irradiated.

Grafts sterilized at 6 million roentgen equivalent physicals were inserted in three dogs for comparison; in all of them there was advancement of healing of the irradiated graft over the control graft of mild to moderate degree. In one, OC28R, a possible con-

tributory factor to this advancement of the healing of the irradiated graft was the presence of a subcutaneous wound infection in the foreleg. In this group, irradiation seemed to cause acceleration of healing rather than retardation (Figs. 8-A and 8-B).

Effects of Irradiation on Bone

Irradiation caused certain gross and microscopic changes in bone grafts before and after implantation. It was noticed that after irradiation the grafts had a yellow to yellow-brown discoloration that was roughly proportional to the dose. It was more marked in the freeze-dried than in the frozen grafts. After implantation and subsequent staining the irradiated grafts demonstrated an increased basophilic reaction that was also roughly proportional to the dose but was not significantly different in the frozen and freeze-dried grafts (Figs. 7-A through 8-B). At the higher doses of irradiation there was a marked line of separation between the newly deposited bone and the residual graft bone, so that the two were not in direct contact in certain areas (Figs. 7-A through 8-B). It cannot be stated whether this was present *in vivo* or whether it was an artifact brought about by the preparation of the slides. Whatever the cause, this did not uniformly impair the invasion and replacement of the graft histologically. On the contrary, at the higher doses there seemed to be an acceleration of revascularization of the frozen grafts and of some of the freeze-dried. It is possible that irradiation causes physiochemical changes in the protein matrix of bone grafts that vary according to the method of preservation at the time of irradiation. These changes in irradiated frozen grafts seem to facilitate invasion and replacement of the graft at higher doses, while higher doses of irradiation seem to cause changes in freeze-dried grafts that retard healing somewhat. However, this advantage for frozen irradiated grafts is outweighed by the over-all superiority of the freeze-dried grafts over frozen grafts, especially at sterilizing dose levels, as shown by Table IX. The superiority of non-irradiated freeze-dried grafts over non-irradiated frozen grafts is the subject of a separate paper [12].

CONCLUSIONS

1. A dose of 1.0 million roentgen equivalent physicals of high-voltage cathode irradiation will adequately sterilize one-eighth-inch-thick sections of freeze-dried and frozen animal bone after bacteriological contamination with *Staphylococcus aureus* (F.D.A. 209).

2. This sterilizing dose does not significantly impair graft healing in the dog.

3. Cathode irradiation of dog-bone grafts at 2.0 to 6.0 million roentgen equivalent physicals results in some impairment of healing in freeze-dried grafts; whereas, it appears to accelerate the healing of frozen grafts. This advantage for frozen irradiated bone is outweighed by the superior rate of incorporation of freeze-dried as compared with that of frozen grafts.

4. Irradiation causes gross and microscopic changes in bone grafts. These consist primarily of a yellow discoloration prior to implantation, increased basophilic staining after implantation, and some impairment of the "cement line" between the graft and the invading host bone. These changes are roughly proportional to the dose of irradiation.

5. Before carrying out controlled clinical studies in patients, an experiment should be performed to determine the doses necessary to sterilize sections of various sizes of human bone that have been grossly contaminated with mixtures of a wide variety of organisms.

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(*Continued from page 861*)

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The Status Bonnevie-Ullrich

Case Presentation

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A patient with status Bonnevie-Ullrich was recently observed in the Department of Orthopaedic Surgery of the State University of Iowa. The case is reported here because of its unusual features and because of the infrequency with which the condition occurs.

HISTORICAL

Kobylinski first described the condition of webbed neck to which Funke, in 1902, gave the name "pterygium colli".

Although previous observations had been made of this peculiar and rare condition, it was not until 1929, when Ullrich described the first case, that it was recognized as a clinical entity. Ullrich described the pathogenesis of this abnormality in human beings at the same time that Kristine Bonnevie observed or produced the same condition experimentally in rats.

In 1924, Bagg and Little observed the development of several abnormalities of the eyelids and feet and modification of hair length in irradiated rat embryos. Bonnevie also demonstrated that in all such irradiated embryos, in the primary developmental stages, a large quantity of spinal fluid was formed which found its way into the subcutaneous tissues through an orifice situated underneath the roof of that which would eventually become the fourth ventricle. Weed demonstrated the presence of this orifice and named it the anterior foramen. Ullrich showed that this foramen was formed temporarily in the human embryo. If the pressure is too great, the spinal fluid is distributed generally throughout the subcutaneous tissues to form bullae. These bullae may persist or disappear, leaving certain residues most commonly in the nose, the mammary glands, fingers, and toes. These residues can be recognized postnatally. This hypothesis was confirmed by Grunwald and Kornfeld, and Blechschmidt and Rossi, who examined a large number of human embryos and found the classical bullae containing spinal fluid in the subcutaneous tissues of the neck [5].

There are two theories regarding the pathogenesis of this abnormality. Bagg, Plegens, and Sturkie [8] maintained that the liquid in these bullae resulted from an increased permeability of the lymphatic vessels. Rossi, however, maintained that hereditary degenerative factors not only cause the deformities observed in this condition, which would explain the polymorphism of the syndrome, but that, acting indirectly, these hereditary factors give rise to the formation of bullae, of either spinal fluid (Bonnevie's theory) or lymphatic fluid (Bagg, Plegens, and Sturkie's theory), and these bullae, themselves, may give rise to other malformations.

In 1938 Turner described a syndrome characterized by (1) pterygium colli, (2) cubitus valgus, (3) infantilism, and (4) retarded closure of the epiphyses. Albright, Smith, and Fraser found this same syndrome in females and thought it to be due to a hypogenesis of the ovaries. Earlier Flavell and Martin and Greenblatt each had described this same condition; Wilkins and Fleischmann compared this syndrome with that described by Ullrich and stated that they were identical [4]. However, although Ullrich later accepted the similarity of both syndromes, he stated that the pathogenesis was different, and maintained that the cases with symmetrical pterygium were probably due to endocrine dysfunction but the asymmetrical forms were due to spinal-fluid bullae.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

On the basis of over 200 case reports, the syndrome of "pterygium" has been subdivided into five groups of conditions exhibiting multiple degeneration[4]:

1. Status Ullrich bilateralis, characterized by pterygium usually of the neck, deformities of the extremities, disturbance in cranial-nerve function, hypoplasia of the mandible, retarded growth, mental retardation, lymphangiectatic oedema, telangiectasia, cutis laxa, hypermobility of joints, deformities of the thorax, muscular hypotonia, deformities of the ears, epicanthus, hypertelorism, high arched palate, and mushroom epiphyses;

2. Dystrophia brevicollis congenita of Nielsen, characterized by "pterygium colli" either bilateral or unilateral, deformities of the cervical vertebrae such as are found in the Klippel-Feil syndrome, and by other manifestations listed in classification *1;*

3. Turner's syndrome, characterized by pterygium, almost always symmetrical and bilateral, hypogonadism, predilection for the female sex, and other findings listed in classification *1;*

4. Status Ullrich unilateralis, characterized by unilateral and asymmetrical pterygium, particularly of the extremities, aplasia of the muscles in the region of the pterygium, and predilection for the male sex.

5. Pterigoartromiodysplasia congenita, characterized by pterygium of the extremities, almost always asymmetrical and unilateral, aplasia of the muscles associated with alterations in the insertions of the muscles, ankylosis of several joints, and other findings listed in classification *1*.

CASE PRESENTATION

J. H., a female, Hospital No. 54-3421, was admitted to the Pediatric Clinic of the State University of Iowa Hospital on March 24, 1954, at the age of thirty-one days because of paroxysmal dyspnoea and multiple congenital anomalies including webbing of the neck and deformities of the ear and feet. The child had been born after a normal pregnancy and labor. The birth weight was five pounds, thirteen and three-fourths ounces. For the first two days of life, the child was kept in an incubator because of recurrent cyanosis. The patient had since had intermittent attacks of dyspnoea. The child was discharged from the lying-in hospital ten days after birth and did fairly well at home until she was brought to the University Hospitals so that further therapy might be considered. Her history is otherwise non-contributory except that the patient had had a generalized macular rash ten days prior to admission which had subsided in a few days.

The family history is interesting in that the father's maternal grandmother was afflicted with a club foot and syndactylism of the fingers of the right hand. The mother's father and brothers both had Legg-Calvé-Perthes disease and had been treated in this Orthopaedic Clinic. Both parents are in good health and do not exhibit any congenital anomalies. The patient is their first child.

The patient was transferred to the Orthopaedic Clinic the day after admission in view of the multiple anomalies found.

Physical examination revealed a malnourished white female child who appeared chronically ill, but not in any apparent distress. She was not very alert and responded sluggishly to stimuli. Her weight was six pounds, twelve and one-fourth ounces and her height was twenty and one-half inches.

The skin overlying the posterior aspect of the neck was arranged in loose vertical folds with the appearance of webbing (Fig. 1). The hair distribution was normal. There was no palpable adenopathy.

The head measured fourteen inches in circumference. There was slight hypertelorism of the eyes, moderate depression of the bridge of the nose, and lateral protrusion of the left auditory auricle. There was a highly arched palate. The distance between the base of the nose and mouth was longer, and the chin was smaller than the normal (Fig. 2).

Percussion and auscultation indicated that the lungs were clear. The respiratory rate was 30. The child became cyanotic with prolonged crying.

The mammary glands were bilaterally enlarged and firm, and both nipples were inverted (Fig. 2).

The cardiac rate was 180 per minute, and the rhythm was regular. No obvious enlargement of the heart could be detected by percussion.

No abnormal masses were palpable in the abdomen. The labia majora were found to be enlarged and the skin overlying them was erythematous.

The extremities had a peculiar non-pitting and non-postural oedema confined to the dorsal aspect of both feet and the left hand, with a dusky discoloration of the overlying skin. The knees revealed a bilateral subluxation of the tibiae on the femora posteriorly. The range of motion of both knees was from 60 degrees of hyperextension to 180 degrees of extension. No flexion was possible. The patellae were not palpable. No abnormal folds were found in the gluteal region or thighs, but the flexed hips could not be abducted to 90 degrees. The spine and upper extremities did not reveal any abnormalities except for the oedema on the dorsum of the left hand (Fig. 2).

The deep tendon reflexes were normal. The Babinski reflexes were positive bilaterally.

The laboratory findings were as follows: Red blood corpuscles, 4.95 million per cubic millimeter; white blood corpuscles, 23,800 per cubic millimeter. Differential blood count: polymorphonuclear neutrophils, 62 per cent, lymphocytes, 30 per cent, and monocytes, 8 per cent. Urinalysis revealed ++++ albumin, sugar 0, blood 0. The microscopic examination did not reveal any abnormal findings.

Roentgenograms of both knees revealed a posterior dislocation of the tibiae on the femora, and a mushroom deformity of the distal epiphyses of the femora and the proximal epiphyses of the tibiae (Fig. 3).

Roentgenograms of the pelvis revealed a bilateral subluxation of the hip joints (Fig. 3).

During hospitalization, an attempt was made to correct the dislocation of the knees by manipulation and the use of casts. During one of these manipulations the patient sustained a supracondylar fracture of the right femur. This healed rapidly with abundant callus.

On July 14, 1954, the patient developed a mucopurulent rhinitis and pneumonitis. Fluoroscopic examination of the heart and chest showed pneumonitis and atelectasis of the right middle lobe with extreme pul-

monary emphysema and depression of each leaf of the diaphragm. The heart was found to be shifted to the right. These findings were confirmed by a roentgenographic examination of the chest (Fig. 4) which, in addition to these findings, also showed a fusiform enlargement about the left seventh, eighth, and ninth ribs, posterolaterally, without an actual disruption of the cortex.

Electrocardiographic tracings were essentially normal.

The pneumonitis and atelectasis were treated by antibiotics and an oxygen tent and they cleared up in a few days.

On July 30, 1954, the patient was discharged at the insistence of the parents. She was to return to the hospital for re-evaluation and consideration of further treatment of her orthopaedic deformities. On the day she was to return, at seven months of age, while in the ambulance, the patient suddenly expired. No autopsy permit could be obtained.

COMMENT

The prognosis of patients afflicted with this syndrome is very poor, the majority of them dying during infancy. Only a few reach the age of puberty. Those who reach the age of puberty exhibit characteristics of nanism and sexual infantilism.

The mechanism of death apparently is a combination of factors, such as inanition and intercurrent disease. A thirteen-year-old child died from gastro-oesophageal hemorrhages and the autopsy revealed diffuse cystic degeneration of the thyroid, ovaries, and liver, hypertrophic cirrhosis of the liver with enlargement of the spleen, and alterations of the excretory, pancreatic, and salivary ducts.

In spite of adequate feedings they lose weight constantly. They have an inability to assimilate their food even in the absence of demonstrable gastro-intestinal pathological condition. Most of them develop pneumonitis, and, in spite of antibiotic and energetic symptomatic treatment, they lose ground until death.

The treatment for the orthopaedic deformities is essentially conservative and consists in gradual manipulations and serial applications of plaster casts.

SUMMARY

A patient with multiple deformities of ectodermal and mesodermal origin has been reported. The findings of pterygium of the neck, deformities of the extremities, hypoplasia of the mandible, retarded growth, lymphangiectatic oedema, cutis laxa, deformity of the ear, ocular hypertelorism, high-arched palate and mushroom epiphyses are typical of the status Ullrich bilateralis. An additional finding, which differs from the usual description, was the hyperplasia of the mammary glands.

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Recurrent Anterior Superior Dislocation of the Glenohumeral Joint

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The following case is presented as an example of anterior superior dislocation of the shoulder. To our knowledge this type of lesion has not been described and, in fact, has generally been considered impossible because of the barrier to upward displacement formed by the acromion and the coraco-acromial ligament.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Photograph showing shoulder in relaxed position without dislocation.
Fig. 1-B: Anterior superior dislocation upon attempted abduction.

FIG. 1-C

FIG. 2-A

Fig. 1-C: Anterior superior dislocation resulting from upward force being applied to the elbow.
Fig. 2-A: Roentgenogram of shoulder, the glenohumeral joint being in the "reduced" position.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Anterior superior dislocation with the arm in abduction.

Fig. 2-C: Anterior superior dislocation resulting from upward force being applied to the elbow.

C. L., a retired brickmason, seventy-three years old, was struck by an automobile on June 17, 1954, while crossing a street. Upon his arrival at the hospital, he was dazed and disoriented. Examination revealed open comminuted fractures of both bones in both legs, multiple rib fractures, and hematuria. A bluish discoloration was apparent over the lateral aspect of the right shoulder, but passive manipulation and roentgenographic examination did not show evidence of fracture or dislocation of the shoulder.

Débridement of the leg wounds and open reduction of the leg fractures were performed. The left anterior tibial artery, which had been severed, was repaired. Gangrenous plaques developed in the left foot in spite of repeated blocking of the lumbar sympathetic nerves. Postoperative recovery was slow, and the patient remained disoriented and uncooperative. Attention was not directed to the shoulder until July 12, twenty-five days after injury, when it was observed that superior dislocation of the right shoulder occurred each time that the patient attempted to abduct his arm (Figs. 1-A, 1-B, and 1-C).

This superior dislocation could be produced at will or passively by applying an upward force to the humerus when it was in either the anatomical or abducted position. Anterior dislocation could not be demonstrated, but superior dislocation could easily be obtained in any position of rotation at the glenohumeral joint. Examination revealed the humeral head to be easily palpable beneath an atrophied deltoid muscle; however, active contraction of the deltoid could be elicited. Atrophy of the infraspinatus and supraspinatus was obvious, and active contraction could not be palpated. The subscapularis apparently was intact as far as its insertion and was capable of active contraction. The tendon of the long head of the biceps brachii was intact, but it would slip medially out of the bicipital groove whenever dislocation occurred or whenever the biceps was contracted against resistance. The coraco-acromial ligament could not be palpated. Since the humeral head became dislocated upward between the coracoid process and the acromion, it is presumed that the ligament had ruptured.

Roentgenograms confirmed the clinical impression of anterior superior dislocation (Figs. 2-A, 2-B, and 2-C).

Operative intervention was considered inadvisable in view of the patient's age and general condition. Fortunately, the disability has been painless, and the patient has made an excellent recovery from his other injuries.

COMMENT

Although the pathological findings in this case were not confirmed by operative exposure, the following lesions could be demonstrated or inferred: (1) Massive tearing or avulsion of the rotator cuff, (2) rupture of the coraco-acromial ligament, and (3) medial displacement of the biceps tendon. This triad constitutes a logical prerequisite to anterior superior dislocation of the glenohumeral joint. The third lesion might also have been rupture or dislocation of the biceps tendon, or any condition of the biceps brachii which would impair its function with regard to stability of the glenohumeral joint.

A Diagnostic Reference File for Orthopaedic Surgery Utilizing a Punch Card *

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It has been, until recently, a source of great annoyance and concern to the senior author that he could not promptly and easily put his hands on the records of a given group of cases in his practice when he desired. A satisfactory and easily used file system has been worked out and employed so successfully on our case files that we are presenting it here, in case others may want to make use of it. It facilitates statistical analysis of groups of cases and affords cross references to the charts of patients in these groups. Designed to meet the need for a simple system suitable for use by the individual practitioner or a large group, it makes no departure from standardized and widely accepted usage. It is presented after its successful application to more than 35,000 cases seen in the practice of the senior author and his associates.

Discussion of a method of coding and classifying medical diagnoses may be beset by confusion concerning the difference between a medical nomenclature and a statistical classification. Clarification of this difference will help forestall questions that are applicable to medical nosology, but that here need not concern us. A diagnostic nomenclature is a set or system of approved terms for describing and recording clinical diagnoses and pathological observations. A statistical classification is the result of classifying such diagnoses, for example, into various categories, the purpose being primarily to enable statistical review of disease data. As stated in *The Standard Nomenclature of Diseases and Operations*, its function is to train medical students, and practising physicians in the use of the clearest and most acceptable diagnostic terms to describe a clinical case. The complete specificity of a nomenclature prevents it from serving satisfactorily as a statistical classification since the requirements for the two are completely different.

The most widely accepted classification of diagnoses is in the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death*. Published in two volumes, the manual furnishes a tabular list of diagnoses each of which is identified by a three-digit rubric or code number. The function of the manual is to aid a capable diagnosis coder or record librarian, with occasional medical advice, to assign the terms and disease names used by the physician to the proper category in the list of diagnoses for the purpose of statistical tabulations. The appended "Table of Diagnoses for Orthopaedic Usage" was taken directly from the manual with an occasional modification as indicated.

The three-digit rubrics, representing the diagnoses in the list, serve as code numbers which are punched by hand onto a punch card. This card has been designed by us so as to permit the coding in similar fashion of much additional data besides the diagnosis. Description of the card and the manner of coding and sorting of the cards will make clear the use of the system in the specialty practice of orthopaedic surgery.

A chart is prepared for each patient and filed alphabetically according to the patient's name. In addition, a punch card (Fig. 1) is prepared for each patient and on it is inscribed his name and the date on which he was first seen for each illness or injury. A new card is prepared for each new illness or injury and the diagnosis and other data are coded onto the card. If serial numbers are used for patient identification, these can either be inscribed or coded by hand punch onto the card.

* Based on an Exhibit presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28 to February 2, 1956.

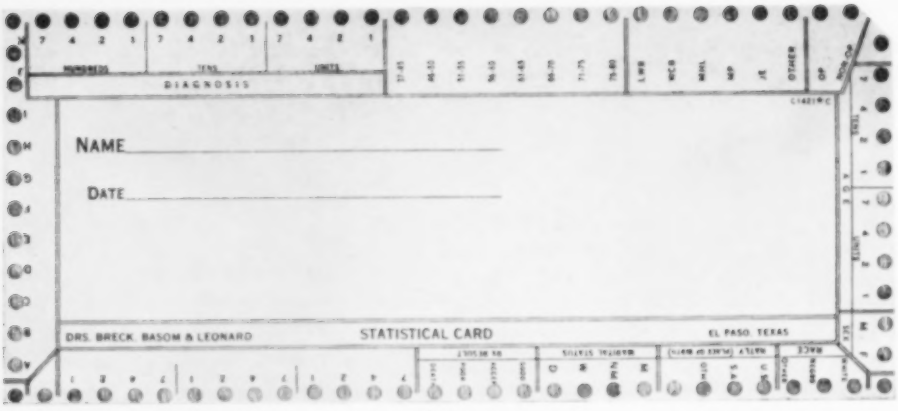

FIG. 1

The punch card as designed for the codification of diagnosis and other data as applied to the authors' orthopaedic practice.

Reference to Figure 1 shows that the punch card is provided with small holes around the periphery of the card for the purpose of coding data. Each hole is identified by a code, which may be a number, letter, word, or abbreviation of a word printed beneath it. By means of a hand punch any of the holes around the edges of the card may be converted to an open notch or slot by punching away that portion of the card between the hole and the edge of the card, thus coding the data to be recorded (Fig. 2).

The punch card illustrated was designed to enable us to record on it much data in addition to the diagnosis assigned to the patient. These data, from left to right around the edges of the card, include the date period in which the patient was first seen, the doctor by whom the patient was treated, whether treatment was operative or not, the age, sex, race, nationality, and marital status of the patient, and the results of treatment. Extra holes remaining have been lettered and allow for the coding of additional data. The kind and amount of data to be coded are an elective matter and it is apparent that this punch card may be designed to suit the purposes of any physician or group. When a large backlog of cases must be coded, we have found it time-saving, at the time of original transfer of data from patient's chart to punch card, to code in addition to the diagnosis only the first three items at the top of the card. This enables each physician to review only his own cases within any group and to separate the cases in which operation was done. He may further select cases according to the five-year period in which they were seen and he may easily separate them into different date periods for purposes of comparison. When dealing with a large backlog of cases it is expedient to reserve coding of such ancillary data as the age, sex and race, of the patient until the time when a particular group of cases is selected for review. Unless one is going to review all cases of sprains of the ankle, for example, it serves no useful purpose to have such subsidiary data recorded.

Reference to Figure 1 shows that, in the section of the card for coding the patient's diagnosis, there are three columns labeled, respectively, units, tens, and hundreds, with four holes above each column to which the values *7*, *4*, *2*, and *1* have been assigned. By punching a single one or a combination of these values, any number from *1* through *9* may be expressed. The manner in which this is done is depicted graphically in Figure 3. It is unnecessary to punch zeros since, if no hole is punched in the units column, zero is understood; and in the tens and hundreds columns the number punched includes the zero.

After all cards have been coded, they are sorted and filed in numerical groups according to diagnosis number. Sorting is accomplished by passing a long needle, similar to a knitting needle, through a conveniently handled stack of cards at a specific hole. When

the needle is raised all cards on which the specific hole has been punched will fall from the stack, the rest remain on the needle as is illustrated in Figure 4. Cards, hand punch, sorting needle, and a manual of instructions concerning coding and sorting are obtainable from the manufacturers and further detail need not be entered into here.

The *Manual of the International Statistical Classification* is published in two volumes, the first of which presents a tabular list of diagnostic categories and a detailed list of the entities included in each diagnostic category. The second volume is an alphabetical index to all diagnoses. The manual's directions are detailed and explicit so that the only comment necessary here concerns the occasional modification we have considered expedient. The appended "Table of Diagnoses for Orthopaedic Usage", taken from Volume I of the manual, includes all orthopaedic conditions and many others not orthopaedic but such as may be seen with sufficient frequency in orthopaedic practice to warrant their inclusion. The table consists of 211 diagnostic categories and may be typed on six standard-size sheets of paper which can be set before the diagnosis coder to facilitate the coding. At the beginning of coding frequent reference to the detailed tabular list in Volume I of the large manual is necessary, but, as familiarity with the entities included in each diagnostic category grows, the more concise table serves as a sufficient guide.

FIG. 2

Coding data by means of a hand punch on the punch card.

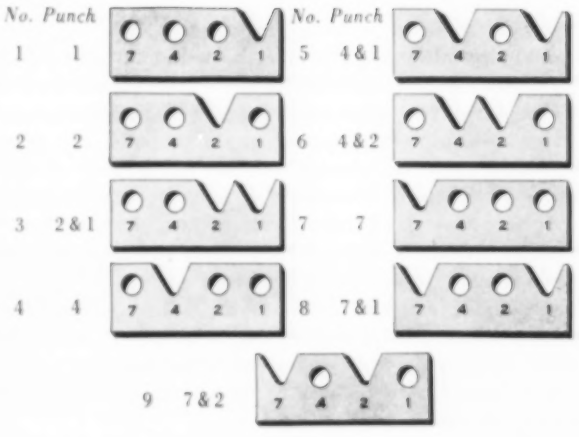

FIG. 3

Showing the special method of coding numbers 1 to 9 on the punch card. This is actually how the card is punched.

FIG. 4

Method of manually sorting the punch cards.

We have found it useful in several instances to subcategorize a diagnostic category. The rubric *807* in the manual, for example, represents the category including fractures of the ribs and sternum. We have chosen to divide this category into its separate entities by adding to the rubric the letter *A* or *B* so that *807A* represents fracture of rib or ribs and *807B* represents fracture of sternum. The entity is coded by punching the number *807* in the columns for diagnosis and by punching the letter *A* or *B* as indicated, at the left hand side of the card. Similarly it has seemed expedient for our purpose to subcategorize categories *812, 813, 821, 823,* and *825.* (See Table of Diagnoses). Were it deemed necessary, because of large numbers of cases or for other reasons, other categories also could be broken down. The requirement that the list of diagnostic categories in a satisfactory statistical classification should be reasonably short must, however, be kept in mind. The use of the rubric with a decimal point and a figure following it will serve equally as well as the use of the rubric followed by a letter. Thus, the category *807* could be subcategorized as *807.1* and *807.2* instead of *807A* and *807B.* Open or compound fractures may be distinguished by punching the letter *K* in addition to the diagnostic rubric and old fractures may be distinguished from fresh or new fractures by punching the letter *J* in addition to the rubric.

In the *Manual of the International Statistical Classification,* sprains and strains of the lower back are included in the two categories *846* and *736.* Category *846* is for acute sprains and strains of the lower back and category *736* is for chronic or old sprains and strains of the lower back. Reference to the manual shows that these categories are defined as follows: *846,* sprains and strains of sacro-iliac region; *736,* affection of the sacro-iliac joint. The entity lumbosacral sprain is included in these categories, lumbosacral sprain or strain, acute, in category *846* and lumbosacral strain, old or chronic, in category *736.* Because the term *lumbosacral* is more commonly used than the term *sacro-iliac* with regard to low-back sprains or strains, we have handled these categories in the following manner. We have retained the original category designation as in the manual but have divided the categories into two parts, designated by the letters *A* or *B.* The rubrics are never coded without an identifying letter: *846,* sprains and strains of the sacro-iliac region; *846A,* sprains and strains, lumbosacral, acute; *846B,* sprains and strains, sacro-iliac, acute; *736,* affection of the sacro-iliac joint; *736A,* affection of the lumbosacral region (sprain, strain, old or chronic); and *736B,* affection of the sacro-iliac joint (sprain, strain, old or chronic).

The rubric *795* in the manual represents the category defined as "Ill-Defined and Unknown Causes of Morbidity and Mortality". We have used it more specifically to represent "No Orthopaedic Condition Found" and it includes those cases in which symptoms are inconclusive and physical and roentgenographic examination fail to reveal a diagnosis. It may also be used for those cases which are referred for physiotherapy only or for the occasional case that may appear in the office by mistake. Similarly the manual has allotted several rubrics to a large group defined as "Symptoms, Senility and Ill-Defined Conditions". Rubric *787* in this group refers to "Symptoms Referable to Limbs and Back," and we have used this rubric when no specific diagnosis has been recorded on the patient's chart but when symptoms were referable to these areas.

The use of this card requires no elaborate machinery for coding, sorting, or tabulating nor does it require special skills. Its technique may be easily learned and applied by a capable secretary or nurse with occasional medical advice as necessary. It is, of course, the physician's responsibility to record as accurate a diagnosis as possible on the patient's chart in accepted terminology.

The "Table of Diagnoses for Orthopaedic Usage" taken from the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death* may, like the parent volumes, be utilized in a diagnostic filing system without the use of punch cards when the volume of cases is small. A simple unprinted card or cards is prepared for

each category as it is reached and the name of the patient is put on the proper card as new patients come to the orthopaedic surgeon and are diagnosed. Similarly this system may be used in conjunction with machine-punched cards when extremely large numbers of cases may warrant large machine methods. Also, data once recorded on the hand-punched card can of course be transferred subsequently to machine-punched cards, should that become desirable.

TABLE OF DIAGNOSES FOR ORTHOPAEDIC USAGE

(Adapted from the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death*, Sixth Revision, adopted 1948)

I. INFECTIVE AND PARASITIC DISEASES

TUBERCULOSIS

012 Tuberculosis of bones and joints, active or unspecified.
013 Late effects of tuberculosis of bones and joints.

SYPHILIS AND ITS SEQUELAE

020 Congenital syphilis.
024 Tabes dorsalis (Charcot's joint; tabetic arthropathy).
027 Other forms of late syphilis (syphilis of bone).
029 Syphilis, unqualified.

GONOCOCCAL INFECTION AND OTHER VENEREAL DISEASES

032 Gonococcal infection of joint.
035 Late effects of gonococcal infection.

OTHER BACTERIAL DISEASES

061 Tetanus.
063 Gas gangrene.

DISEASES ATTRIBUTABLE TO VIRUSES

080 Acute poliomyelitis.
081 Late effects of acute poliomyelitis.
081-A Late effects of acute poliomyelitis (spine and trunk).
081-B Late effects of acute poliomyelitis (upper extremity [ies]).
081-C Late effects of acute poliomyelitis (lower extremity [ies]).
081-D Late effects of acute poliomyelitis (multiple and ill defined).

OTHER INFECTIVE AND PARASITIC DISEASES

132 Actinomycosis.
133 Coccidioidomycosis.
134 Other fungus infection (madura foot).
138 Other infective and parasitic diseases.

II. NEOPLASMS

MALIGNANT NEOPLASMS

170 Malignant neoplasm of breast.
177 Malignant neoplasm of prostate.
193 Malignant neoplasm of brain and other parts of nervous system.
196 Malignant neoplasm of bone.
197 Malignant neoplasm of connective tissue.
199 Malignant neoplasm of other and unspecified sites.
200 Lymphosarcoma and reticulosarcoma.
203 Multiple myeloma (plasmocytoma).

BENIGN NEOPLASMS

221 Pilonidal cyst.
223 Benign neoplasm of brain and other parts of nervous system (Morton's toe, neuroma, neurofibroma).
225 Benign neoplasm of bone and cartilage.
226 Lipoma.
227 Other benign neoplasm of muscle and connective tissue.
228 Hemangioma and lymphangioma.
229 Benign neoplasm of other and unspecified organs and tissues.

NEOPLASMS OF UNSPECIFIED NATURE

237 Neoplasm of unspecified nature of brain and other parts of nervous system (spinal-cord tumor unspecified).
238 Neoplasm of unspecified nature of skin and musculoskeletal system.

III. Allergic, Endocrine System, Metabolic, and Nutritional Diseases

260 Diabetes mellitus (diabetic gangrene, infection, ulcer).
271 Diseases of parathyroid gland (osteitis fibrosa cystica).
280 Beriberi (beriberi neuritis).
283 Active rickets.
284 Late effects of rickets.
285 Osteomalacia.
287 Obesity, not specified as of endocrine origin.
288 Gout.
289 Other metabolic diseases (lipoidosis, eosinophilic granuloma of bone).

VI. Diseases of the Nervous System and Sense Organs

351 Cerebral spastic infantile paralysis.
352 Other cerebral paralysis (cerebral vascular accident, old or late effects).
362 Brachial neuritis.
363 Sciatica (without disc).
364 Polyneuritis and polyradiculitis.
366 Other and unspecified forms of neuralgia and neuritis (neuralgia, intercostal).

VII. Diseases of the Circulatory System

450 General arteriosclerosis.
453 Peripheral-vascular disease (Raynaud's, Buerger's).
454 Arterial embolism and thrombosis.
455 Gangrene of unspecified cause.
460 Varicose veins of lower extremities.
462 Varicose veins of other specified sites.
463 Phlebitis and thrombophlebitis of lower extremities.
464 Phlebitis and thrombophlebitis of other sites.
465 Pulmonary embolism and infarction.

XII. Diseases of the Skin and Cellular Tissue

690 Boil and carbuncle.
691 Cellulitis of finger and toe.
692 Other cellulitis and abscess without mention of lymphangitis.
693 Other cellulitis and abscess with lymphangitis.
696 Infectious warts (plantar warts).
709 Corns and callosities.
710 Other hypertrophic and atrophic conditions of skin.
712 Diseases of nail (ingrown toenails).
715 Chronic ulcer of skin.
716 Other diseases of skin.

XIII. Diseases of the Bones and Organs of Movement

ARTHRITIS AND RHEUMATISM

720 Acute arthritis due to pyogenic organisms.
721 Acute non-pyogenic arthritis.
722 Rheumatoid arthritis and allied conditions.
723 Osteo-arthritis (arthrosis) and allied conditions.
723-A Osteo-arthritis, cervical (neck-shoulder syndrome).
723-B Osteo-arthritis, spine (thoracic, lumbar, sacral).
723-C Osteo-arthritis, joints, upper extremity.
723-D Osteo-arthritis, joints, lower extremity.
724 Other specified forms of arthritis.
725 Arthritis, unspecified.
726 Muscular rheumatism.
727 Rheumatism unspecified.

OSTEOMYELITIS AND OTHER DISEASES OF BONE AND JOINT

730 Osteomyelitis and periostitis.
731 Osteitis deformans.
732 Osteochondrosis.
733 Other diseases of bone.
734 Internal derangement of knee joint.
735 Displacement of intervertebral disc.
736 Affection of sacro-iliac joint.
736-A Affection of lumbrosacral region (sprain, strain, old or chronic).
736-B Affection of sacro-iliac joint (sprain, strain, old or chronic).

737 Ankylosis of joint.
738 Other diseases of joint.

OTHER DISEASES OF MUSCULOSKELETAL SYSTEM

740 Bunion.
741 Synovitis, bursitis, and tenosynovitis without mention of occupational origin.
741-A Synovitis.
741-B Bursitis.
741-C Tenosynovitis (tennis elbow).
741-D Ganglion.
742 Synovitis, bursitis, and tenosynovitis of occupational origin.
743 Infective myositis and other inflammatory diseases of tendon and fascia.
744 Other diseases of muscle, tendon, and fascia.
745 Curvature of spine.
746 Flat-foot.
747 Hallux valgus and varus.
748 Club-foot.
748-A Talipes equinovarus.
748-B Talipes calcaneovalgus.
748-C Pes cavus.
748-D Metatarsus varus.
748-E Other types of club-foot.
749 Other deformities (acquired or congenital).
749-A Coxa valga and vara.
749-B Genu valgum and varum.
749-C Cubitus valgus and varus.
749-D Mallet finger.
749-E Hallux rigidus and hammer-toe.
749-F Deformity (acquired) of chest and pelvis.

XIV. CONGENITAL MALFORMATIONS

751 Spina bifida and meningocele.
758 Congenital malformations of bones and joints.
758-A Congenital dislocation of hip.
758-B Chondrodystrophy.
758-C Congenital malformations of skull.
758-D Brittle bones.
758-E Cervical rib (scalenus anticus syndrome).
758-F Congenital anomalies, lumbosacral region.
758-G Other congenital malformations of bones and joints (congenital abscence or deformity).
759 Other and unspecified congenital malformations, not elsewhere classified.

N XVII. CLASSIFICATION OF ACCIDENTS, POISONINGS, AND VIOLENCE BY NATURE OF INJURY, FRACTURE AND FRACTURE-DISLOCATION (Compound fractures are coded by punching hole for letter *K*. Old fractures healed, malunion, or non-union are coded by punching hole between *J* and *K*.)

FRACTURE OF SPINE AND TRUNK

805 Fracture and fracture-dislocation of vertebral column, without mention of spinal-cord lesion.
806 Fracture and fracture-dislocation of vertebral column, with spinal-cord lesion.
807 Fracture of ribs and sternum.
807-A Fracture of rib.
807-B Fracture of sternum.
808 Fracture of pelvis.
809 Multiple, and ill defined fractures of trunk.

FRACTURE OF UPPER LIMB

810 Fracture of clavicle.
811 Fracture of scapula.
812 Fracture of humerus.
812-A Fracture of humerus (head and neck).
812-B Fracture of shaft of humerus, except distal end.
812-C Fractured of distal end of humerus (supracondylar, intercondylar, and transcondylar).
813 Fracture of radius and ulna.
813-A Colles's fracture.
813-B Reversed Colles's or Smith fracture.
813-C Fracture of radius alone.
813-D Fracture of ulna alone.

813-E Fracture of both bones forearm other than Colles's or Smith.
814 Fracture of carpal bone(s).
815 Fracture of metacarpal bone (s).
816 Fracture of one or more phalanges of hand.
817 Multiple fractures of hand bones.
818 Other, multiple, and ill defined fractures of upper limb.
819 Multiple fractures involving both upper limbs, and upper limb with rib and sternum.

FRACTURE OF LOWER LIMB

820 Fracture of neck of femur.
821 Fracture of other and unspecified parts of femur.
821-A Fracture of shaft of femur, except distal end.
821-B Fracture of distal end of femur (supracondylar, transcondylar, and intercondylar).
822 Fracture of patella.
823 Fracture of tibia and fibula.
823-A Fracture of both leg bones.
823-B Fracture of tibia alone.
823-C Fracture of fibula alone.
824 Fracture of ankle (malleolus [i]).
825 Fracture of one or more tarsal and metatarsal bones.
825-A Fracture of tarsal bones.
825-B Fracture of metatarsals.
826 Fracture of one or more phalanges of foot.
827 Other, multiple, and ill defined fractures of lower limb.
828 Multiple fractures involving both lower limbs, lower with upper limb, and lower limb(s) with rib(s) and sternum.
829 Fracture of unspecified bones.

DISLOCATIONS WITHOUT FRACTURE

830 Dislocation of neck, jaw.
831 Dislocation of shoulder.
832 Dislocation of elbow.
833 Dislocation of wrist.
834 Dislocation of finger.
835 Dislocation of hip.
836 Dislocation of knee.
837 Dislocation of ankle.
838 Dislocation of foot.
838-A Dislocation of foot.
838-B Dislocation of toes.
839 Other, multiple, and ill defined dislocations.

SPRAINS AND STRAINS OF JOINTS AND ADJACENT MUSCLES

840 Sprains and strains of shoulder and upper arm.
841 Sprains and strains of elbow and forearm.
842 Sprains and strains of wrist and hand.
843 Sprains and strains of hip and thigh.
844 Sprains and strains of knee and leg.
845 Sprains and strains of ankle and foot.
845-A Sprains and strains of ankle.
845-B Sprains and strains of foot.
845-C Sprains and strains of toes.
846 Sprains and strains of sacro-iliac region.
846-A Sprains and strains lumbosacral, acute.
846-B Sprains and strains sacro-iliac, acute.
847 Sprains and strains of other and unspecified parts of back.
848 Other and ill defined sprains and strains.

INTERNAL INJURY OF CHEST, ABDOMEN, AND PELVIS

860 Traumatic pneumothorax and hemothorax (complication, rib fractures).
863 Injury to gastro-intestinal tract.
867 Injury to pelvic organs.
869 Internal injury unspecified or involving intrathoracic with intra-abdominal organs.

LACERATION AND OPEN WOUND OF FACE, NECK AND TRUNK

(Open wound includes diagnosis foreign body which has penetrated).
874 Open wound of neck.

875 Open wound of chest.
876 Open wound of back.
877 Open wound of buttock.
879 Multiple and unspecified open wounds of face, neck, and trunk.

LACERATION AND OPEN WOUND OF UPPER LIMB

880 Open wound of shoulder and upper arm.
881 Open wound of elbow, forearm, and wrist not involving tendons.
882 Open wound of wrist involving tendon (s).
883 Open wound of hand, except finger (s).
884 Open wound of finger (s).
885 Multiple and unspecified open wounds of one upper limb.
886 Traumatic amputation of thumb (s).
887 Traumatic amputation of finger (s).
888 Traumatic amputation of arm and hand.

LACERATION AND OPEN WOUND OF LOWER LIMB

890 Open wound of hip and thigh.
891 Open wound of knee, leg (except thigh), and ankle not involving tendons.
892 Open wound of ankle involving tendons.
893 Open wound of foot, except toe (s).
894 Open wound of toe (s).
895 Multiple and unspecified open wounds of one lower limb.
896 Traumatic amputation of toe (s).
897 Traumatic amputation of foot.
898 Traumatic amputation of leg.

LACERATION AND OPEN WOUNDS OF MULTIPLE LOCATION

900 Multiple open wounds of both upper limbs.
901 Multiple open wounds of both lower limbs.
902 Multiple open wounds of both upper and lower limb (s).
903 Multiple open wounds of both hands.
904 Multiple open wounds of both head and limb.
905 Multiple open wounds of both head and trunk.
906 Multiple open wounds of both trunk and limb.
907 Multiple open wounds of face with other sites.
908 Multiple open wounds of unspecified location.

SUPERFICIAL INJURY

910 Superficial injury of neck and face.
911 Superficial injury of trunk.
912 Superficial injury of shoulder and upper arm.
913 Superficial injury of elbow, forearm, and wrist.
914 Superficial injury of hand (s), except fingers.
915 Superficial injury of finger (s).
916 Superficial injury of hip, thigh, leg, and ankle.
917 Superficial injury of foot and toe (s).
918 Superficial injury of other, multiple, and unspecified sites.

CONTUSION AND CRUSHING WITH INTACT SKIN SURFACE

920 Contusion of face and neck, except eye (s).
922 Contusion of trunk.
923 Contusion of shoulder and upper arm.
924 Contusion of elbow, forearm, and wrist.
925 Contusion of hand (s), except fingers.
926 Contusion of finger (s).
927 Contusion of hip, thigh, leg, and ankle.
928 Contusion of foot and toe (s).
929 Contusion of other, multiple, and unspecified sites.

BURNS

943 Burn confined to upper limb (s), except wrist and hand.
944 Burn confined to wrist (s) and hand (s).
945 Burn confined to lower limb (s).

INJURY TO NERVES AND SPINAL CORD WITHOUT BONE INJURY

952 Injury to nerve (s) in upper arm.
953 Injury to nerve (s) in forearm.
954 Injury to nerve (s) in wrist and hand.

955 Injury to nerve (s) in thigh.
956 Injury to nerve (s) in leg.
957 Injury to nerve (s) in ankle and foot.
959 Other nerve injury including nerve injury in several parts.

EFFECTS OF WEATHER, EXPOSURE, AND RELATED CONDITIONS

980 Effects of reduced temperature (frozen extremity[ies]).

995 Certain early complications of trauma. (This title is not used if the antecedent condition is present. When, however, it is old, healed, long since past, or unknown, this title is used. Volkmann's ischaemic contracture of late onset is included here).
999 Adverse reaction to other therapeutic procedure. Amputation stump, abnormal, painful, or with late complications, included here.
795 No orthopaedic condition present. Not orthopaedic case. Referred for physical therapy only. Ill defined or unknown.
787 Symptoms referable to limbs and back. This category is used when no more specific diagnosis than such diagnoses as *metatarsalgia, painful feet* is assigned, no indication given as to any underlying cause or pathological process.

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DISCUSSION

Congenital Neurofibromatosis

(*Continued from page 731*)

rather similar to those described by Dr. McCarroll. In our group, however, we have had no metastatic lesions recorded. We did have one patient who seemed to have a malignant lesion of the forearm. This was a boy six years of age who had a local lesion of bone and an erosive or pressure lesion of bone associated with soft-tissue tumor. The visible tumor tissue was removed, but it was extensive and could not be removed *en masse* without sacrificing the forearm. Histologically, the tissue was diagnosed as neurofibroma and was considered to be benign. This first procedure was in April 1943. There was rapid recurrence with further invasion of bone and extension of the tumor up the forearm to the elbow; amputation was performed above the elbow in August 1943. In 1951, he returned complaining of pain in his stump. Thickening was palpable along the medial ulnar nerves extending down into the end of the stump. The involved areas were approached surgically and were excised. Histological interpretation was that of neuroma, not tumor. Since that time he has had no other lesions.

We too have attacked the massive neurofibromatous involvement of soft tissues and of the peripheral nerves locally and have excised such neurofibromatous tissue extensively. We have preserved nerve trunks but have incised their sheaths when indicated and dissected the neurofibromatous tissue from them. On occasion this has been followed by improvement in the function of peripheral nerves.

During the period of growth of the child in particular, however, these soft-tissue tumors grow and grow. In some children with multiple areas of involvement the decision of what to do may be difficult. The potentiality of malignant metaplasia is appreciated; but if one lesion with such potentiality is removed, there are likely to be other areas that have equal potentiality. Furthermore, even if the involvement is such as to suggest amputation, the nerve trunks of the extremity at a proximal level may be so involved as to interfere with the use of a prosthesis.

We need to know still more about the life history of this disease, and I hope that Dr. McCarroll continues his interest in following these patients and others with the disease. It is a remarkable group of cases.

One small question arises as to the implication he makes when he adds primary neurogenic involvement to his categories. I ordinarily consider the neurofibroma to be always neurogenic in origin and all other manifestations to be secondary, in many of which the mechanism remains obscure.

Coxa Plana in Dizygotic Male Twins

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The occurrence of coxa plana in dizygotic twins is unusual. The literature has so few reports of the affection in twins that a report on coxa plana in dizygotic twins* treated at the Alfred I. duPont Institute would appear to be of sufficient interest to warrant publication.

CASE REPORTS

CASE 1, R. F. C. (No. 3755). A white dizygotic twin boy, three years and three months old, was seen in the Alfred I. duPont Institute Out-Patient Department on February 1, 1952, with the chief complaint of a right-sided limp of two weeks' duration. The onset was sudden, and there was no history of trauma, strain, or infection. The limp remained marked even after periods of rest. Roentgenograms confirmed the clinical impression of coxa plana of the right hip. The child entered the hospital on March 24, 1952.

The past history showed that the child had had chickenpox at the age of three months and bronchial pneumonia at the age of one year. The birth record showed the patient to have been delivered in the frank breech position; the gestation period had been eight months, labor two hours, and the birth weight four pounds, three ounces. The family history showed that the child's dizygotic male twin and two siblings were in apparently normal health. A third cousin (female) had been treated in another hospital for coxa plana of the right hip. The review of systems was essentially normal.

Physical examination revealed a well developed, well nourished male whose complaint was pain in the right hip region. Ear, eye, nose, and throat examinations were negative, and the chest, heart, and abdomen were found to be normal. The gait showed a limp on the right with a moderate amount of atrophy of the right lower extremity. There was a limitation of 25 degrees of lateral rotation in the right hip but all other motions were normal. There was tenderness in the anterior and anterolateral aspects of the right hip with spasm.

The laboratory studies were as follows: Urinalysis was normal; red blood cells 4,470,000 per cubic millimeter of blood, hemoglobin 13.5 grams per 100 milliliters of blood; white blood cells 7,200 per cubic millimeter with a differential count of 50 per cent neutrophils, 48 per cent lymphocytes, 1 per cent basophils, and 1 per cent monocytes; blood specific gravity 1.052, plasma specific gravity 1.027, and plasma protein 7.0 grams per 100 milliliters; sedimentation rate 21 millimeters in one hour (Cutler method), but this fell to 10 millimeters in three weeks' time; blood calcium 12.4 milligrams per 100 milliliters, phosphorus 6.0 milligrams per 100 milliliters, alkaline phosphatase 1.2 Bodansky units; Wassermann and Kahn tests were negative, and tuberculin test (O. T., 1:10,000) was negative.

Roentgenograms (Fig. 1-A) showed coxa plana of the right hip with flattening and irregularity of ossification of the capital femoral epiphysis and widening of the femoral neck. The left hip was normal. Roentgenographic studies for anteversion showed +7 degrees in the right hip and +13 degrees in the left. The angle of the shaft and neck (angle of inclination) was 134 degrees bilaterally. The bone age was compatible with the male standard of bone age at twenty-one months,[22] although the child's chronological age was thirty-nine months.

Course in the Hospital

The patient was placed in traction for several weeks followed by strict bed rest. Clinically a full range of normal motion was present within a month after admission.

With the exception of an occasional upper respiratory infection, there was nothing eventful about the convalescence. On March 26, 1953, one year after admission, the patient received gait training and became ambulatory using a shoulder-leg sling on the right. He was discharged on April 19, 1953, thirteen months after admission.

Follow-up

Weight-bearing was first allowed thirty-two months after treatment was started. The child was last seen on March 23, 1955, three years after his original admission, and, at this time, was able to walk bearing

* Although finger prints and cross-transfers of skin grafts were not performed, the following facts distinguished these children as dizygotic rather than monozygotic twins: (1) Upon delivery, two separate placentae with two separate chorions were noted [12, 19]. (2) The texture and color of the skin and hair, as well as the color and pattern of the iris, were different [18]. (3) The blood groups of the twins were dissimilar in the major and minor components.

his full weight on the extremity. Examination revealed a normal range of painless motion in the right hip. Improvement as shown by roentgenograms was considered satisfactory (Fig. 1-B).

Case 2. J. R. C. (No. 3844). At the age of three years and five months, the twin brother of the first patient (Case 1) was seen at the Alfred I. duPont Institute Out-Patient Department for a roentgeno-

Fig. 1-A

(R. F. C.) Roentgenogram made at admission, showing coxa plana of the right hip with a small, thin, and flattened femoral head. The femoral epiphysis in the stage of degeneration shows irregular decalcification, and the femoral neck is widened. The left hip is normal.

Fig. 1-B

Roentgenogram made thirty-six months after admission. The femoral head is well rounded, not deformed. Recalcification is nearly complete. The head now looks larger and the neck shorter and wider than before treatment.

graphic study of his hips because his twin had been diagnosed and was under treatment for coxa plana of the right hip.

The past medical history showed that the child had had chickenpox at three months, and, at two years of age, had undergone cranial surgery for premature closure of the sagittal sutures. This child, also, had been delivered in the frank breech position, a few minutes after his twin brother. The birth weight was approxi-

FIG. 2-A

(J. R. C.) Roentgenogram made at admission. This anteroposterior view shows almost complete regeneration and recalcification of the right femoral epiphysis. There is degeneration in the left epiphysis, mainly through the medial and lateral portions. The femoral neck is short and thick.

FIG. 2-B

Lateral view of the hips made at admission shows bilateral coxa plana with the right femoral epiphysis in the regeneration stage. The left femoral epiphysis is irregular, small, and flattened.

FIG. 2-C

Roentgenogram made thirty-five months after admission. The left femoral head is now almost completely regenerated with the exception of a small central portion. The femoral neck has now lengthened and is much narrower.

mately four pounds and four ounces, practically the same as his twin. (The family history is given in Case 1). Review of systems was essentially normal.

Physical examination revealed a well developed, well nourished, white male with no complaints. Ear, eye, nose, and throat examinations were negative. The skull measured 53 centimeters in circumference, 12 centimeters in diameter, and 22 centimeters in length. The examinations of the chest, heart, and abdomen were normal. There was a slight limitation of motion in both hips in all directions. Roentgenograms revealed a bilateral coxa plana. The child entered the hospital on April 21, 1952.

The laboratory studies were as follows: Red blood cells 4,650,000, hemoglobin 14 grams per 100 milliliters of blood; white blood cells 5,800 with a differential count of 52 per cent neutrophils, 47 per cent lymphocytes, and 1 per cent eosinophils; blood specific gravity 1.051, plasma specific gravity 1.025, and plasma protein 6.7 grams per 100 milliliters; sedimentation rate 8 millimeters in one hour (Cutler method); blood calcium 13 milligrams per 100 milliliters, phosphorus 5.7 milligrams per 100 milliliters, and alkaline phosphatase 2.0 Bodansky units; Wassermann and Kahn tests were negative, and the tuberculin test (O. T. 1:10,000) was negative.

Roentgenograms showed bilateral coxa plana with flattening and fragmentation of both capital femoral epiphyses, the most severe involvement being in the left hip (Figs. 2-A and 2-B). Roentgenographic studies for anteversion showed +12 degrees of anteversion in the right hip and +22 degrees in the left hip. The angle of the shaft and neck (angle of inclination) was 140 degrees on the right and 136 degrees on the left. Bone age was compatible with the male standard of bone age at twenty-one months [22] although chronological age at this time was forty-one months. It is of some interest that the other twin's bone age was the same as this although his chronological age when he was admitted was thirty-nine months.

Course in the Hospital

The child was treated by strict bed rest; no traction was necessary.* On May 22, 1953, ambulation was allowed and the child was instructed in the use of the shoulder-leg sling on the right. He was discharged on June 13, 1953, approximately fourteen months after admission.

Follow-up

Full weight-bearing was allowed thirty-two months after treatment was started (three months before the roentgenogram in Figure 2-C was made). The child was last seen on March 3, 1955, two years and eleven months after admission. He was bearing full weight on both lower extremities and showed a painless full range of hip motion bilaterally. Improvement by x-ray was considered satisfactory (Fig. 2-C).

* The author did not initially treat or examine the twins.

DISCUSSION

The Occurrence of Coxa Plana in Twins

Since the recognition of coxa plana as an orthopaedic entity by Waldenström in Sweden in 1909, by Legg of Boston, by Calvé in France, and by Perthes in Germany in 1910, numerous articles and publications have attempted to explain the etiology of this perplexing hip affection. The author's presentation is in no way directed toward an explanation of the nature of the disease, but it is simply a report of case studies of coxa plana in dizygotic male twins.

On reviewing the literature with specific reference to the occurrence of coxa plana in twins, few publications were found concerning its occurrence in monozygotic (or uniovular), dizygotic (or biovular) twins, or in twins from a single ovum in which division into two identical parts had taken place before each part was fertilized by separate spermatozoa [4]. As pointed out by Giannestras [5], "No reports were found of true Legg-Perthes disease occurring in twins, without other stigmata of diffuse epiphysitis." Resnick discussed the occurrence of coxa plana in identical male twins and in their mother, but a concurrent condition of multiple osteochondrosis was present. Their condition represented a generalized epiphyseal dysplasia rather than one localized to the region of the hip.

Hagen reported the presence of familial coxa plana; however, the disease process did not involve twins. Cavanaugh, Shelton, and Sutherland studied members of the families of patients with coxa plana and discovered a high familial incidence of metabolic disorders — particularly colloid goiter — and concluded that the etiology of the coxa plana was hypothyroidism. Hagen also presented case studies of siblings with coxa plana. Linderman reported in his original article the appearance of Legg-Perthes disease in monozygotic and dizygotic twins which was in association with bilateral coxa vara, and which did not occur as a separate phenomenon. Goff reported in his Newington series fraternal twins (one male and one female) with coxa plana present in only one twin [8]. Hamsa and Campbell noted a familial tendency toward coxa plana in three male siblings, none of whom were twins.

The findings in the author's cases of bilateral coxa plana in twins, in one of whom there were no symptoms, can only substantiate the fact of the insidious onset of this hip condition and emphasize the importance of obtaining roentgenograms even with minor hip complaints in the young. This is especially true if there is a family history of coxa plana. The finding of an elevated sedimentation rate, 21 millimeters in one hour (Cutler method) in Case 1, is interesting, but it probably had no relationship to the hip condition. Gill stated that in his series "the blood sedimentation rates have always been within normal limits."

Retardation of Bone Growth

It is of some interest that both twins showed some retardation of bone growth, their bone ages being considerably less than their chronological ages. Furthermore, the twin in Case 2 (J. R. C.) had cranial synostosis.

Gill found unexplained skeletal retardation in four of the twenty cases of coxa plana which he studied. There was no evidence of hypothyroidism in any of them. Katz also found no relationship between coxa plana and hypothyroidism. Markovits listed many causes for retardation of bone growth, none of which are applicable to these dizygotic twins. Goff, using complementary feedings of aureomycin in patients with coxa plana, claimed acceleration of growth up to 30 per cent.[9] At the present state of our knowledge, the co-existence of coxa plana and retardation of bone growth must be considered coincidental.

Differential Diagnosis of Coxa Plana Roentgenographically

The differential diagnosis of coxa plana from the roentgenographic viewpoint may

at times prove difficult. With an adequate history and with the appropriate clinical and laboratory data available, however, such diseases as acute synovitis, acute transient epiphysitis, tuberculosis, acute osteomyelitis, pyogenic arthritis, acute rheumatoid arthritis, slipping of the femoral capital epiphysis, congenital coxa vara, and congenital dislocation of the hip can be ruled out without difficulty. The following diseases are less well known and deserve some comment.

Multiple ossification centers. These are variations in the normal skeletal development and are not found in more than one epiphysis. The centers are osseous rather than calcific, and are larger than those seen in dysplasia epiphysialis multiplex. The metaphysis is not involved. No other evidence of bony impairment is seen in a skeletal survey [3].

Hypothyroidism. This condition shows a delay and irregularity in the calcification of the epiphyses with a fragmentation and stippled appearance. The multiple centers fuse slowly. The condition is generalized and the linear growth of the long bones, as well as dentition, is delayed. Hypometabolism, hypercholesteraemia, decreased protein-bound iodine of plasma, and decreased uptake of radioactive iodine in the thyroid confirm the diagnosis of hypothyroidism [24].

Dysplasia epiphysialis multiplex is characterized on roentgenograms by the mottled, irregular density of several epiphyseal centers. This is in contrast to a single epiphyseal involvement seen in multiple ossification centers [17]. Linear dwarfism and stubby phalanges are present, although there is no evidence of hypothyroidism. The epiphyses appear to have multiple centers which are late in appearing, but closure of the epiphyseal plate is not delayed. Metaphyseal involvement causes broadening of the femoral neck but not the degeneration found in coxa plana.

Chondrodystrophy may cause broadening of the femoral head and neck with contour defects of the head and widening of the cartilaginous joint space. There is, however, no flattening of the femoral head or increased density within the femoral head. These findings combined with the generalized bony involvement seen in chondrodystrophy should make the diagnosis clear.

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A Postoperative Arm-Suspension Sling

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Arm suspension and ice bags are routinely ordered at the New York Orthopaedic Hospital for patients who have had surgery on the hand and forearm. While improvised equipment served the purpose, a more efficient method was sought.

In an attempt to meet this need, an arm-suspension sling designed by the writer was submitted and tried out in February 1955. Refinements were made. During the next three months this improved device was utilized for twenty-six patients, admittedly a small but a representative group. In the trial period favorable reactions were elicited from both the patients and the attending physicians. Subsequently, the sling to be described was officially accepted. No claim of perfection is made, although there are no present indications for further modification.

This simple one-piece device provides for the suspension of the arm flexed at the elbow, support of the forearm, and application of ice bags (Fig. 1). There is one main section forty-four inches long by thirteen inches wide, folded in half crosswise to serve as a sling. Both halves have identical features.

Inside, there are four flaps spaced to come together in adjoining pairs when the sling is folded. These flaps, partially attached, enclose the forearm and hold it in place when the free, adjacent ends are pinned together.

Outside, two similar pockets accommodate ice bags. The latter, turned upside down, are held at the desired level by a tie above the pocket at the top center of the sling. Two

FIG. 1

FIG. 2

Fig. 1: Patient with arm-suspension sling in place.

Fig. 2: The outside features of the unfolded sling are demonstrated. Identical features of each half are illustrated. Pocket (shaded area) holds an ice bag which is secured in place by the tie (held by nurse) at the top of the sling. Two strips, hanging from each pocket, are brought up and the ends are tied to the adjacent ones when the sling is folded.

strips, partially attached across the pocket, are tied at the sides of the sling to the adjacent ones to hold the ice bags against the part.

The method of use is shown in Figure 1. The spreaders are inserted through the open sides of the wide hems at the top of the folded sling. The spreaders are then supported by short ropes. Rings looped around the center of the ropes are attached to a snap which is fastened to another short rope. The latter is tied at the desired height to a pole to maintain suspension of the arm.

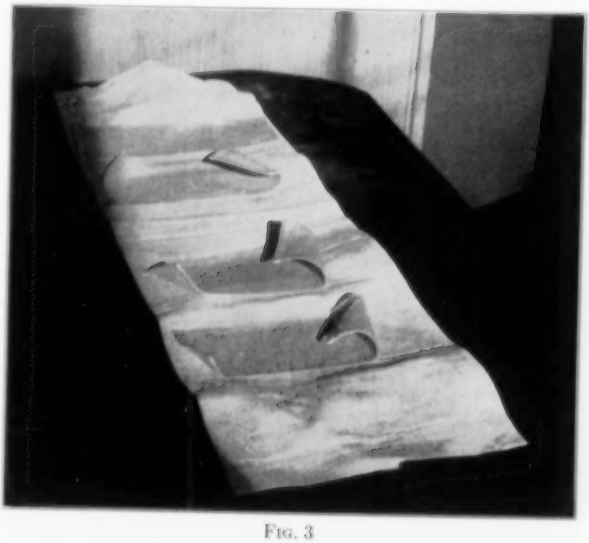

FIG. 3
Inside of unfolded sling showing flaps.

Not seen in Figure 1 are four safety pins used to secure the ends of the inside flaps. In addition, a small combine pad is placed under the elbow inside the sling, for cushioning effect as the elbow rests on the mattress.

After use, the sling is dismantled and laundered. It saves time if clean slings are reset with spreaders, ropes and rings instead of storing these articles separately.

The sewing room in the hospital was able to construct slings for our purpose following the approved model with pattern and sewing instructions. Fifty-two inches of light-weight canvas seventy-four inches wide will make two slings, all pieces to be cut on the grain of the material. Because of their straight design, these pieces are easy to finish and to put together. Unfortunately, within the limited scope of this paper, it is not feasible to include detailed directions for making the pattern and for sewing.

In our experience, this device has proved to be better and more efficient than the improvised equipment formerly used. It is more economical of material, time and energy, has a neater and a more attractive appearance, and is simpler to use. Moreover, it promotes the desired therapeutic effect with greater comfort to the patient.

A Simple Method for Elastic Splinting of the Thumb Web

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From the Hand Service, Sahlgren's Hospital, Göteborg

The ideal splint to widen a contracted thumb web has yet to be found. However, a good way to obtain the desired result is the use of the following device.

A rubber or elastic plastic tube about fifteen millimeters in diameter and sixty to eighty millimeters in length is split open. Its concave surface is then placed along the web in the way shown in Figure 1. The tension can be modified by cutting away different

FIG. 1

FIG. 2

amounts from the split sides of the tube as shown in Figure 2. The tube is less apt to irritate the skin if it is lined with adhesive tape. Adhesive tape can also be used to keep it in place, if necessary. The hand is easy to use with this splint, even at work. It is also good for permanent use when there is loss of abductor function, as in some patients as a result of poliomyelitis.

The splint is likewise useful when it is difficult to separate the fingers because of oedema or contracture, as, for example, in the postoperative period after surgical treatment for Dupuytren's contracture.

Orthopaedic Surgery in Australia

By R. I. Harris, M.B., F.R.C.S.(C), Toronto, Ontario, Canada

The Commonwealth of Australia is an island continent, 3,000,000 square miles in extent. It is slightly smaller than the United States (3,500,000 square miles) or Canada (3,700,000 square miles) or continental Europe (3,750,000 square miles). The population is now just over nine million, having increased one million by immigration since the end of the war. The great bulk of the population is concentrated on the eastern coast and on the eastern end of the south coast. There is a thin sprinkling of population in the center of the north coast and down the west coast, especially at the southwest corner of the continent. The heart of the continent is semi-arid and very thinly populated. In this respect it bears some resemblance to Canada whose arctic and sub-arctic regions are equally vast, thinly populated, and incapable of supporting crops. Two cities have populations of over one million: Sydney (nearly 2,000,000) and Melbourne (1,600,000).

In 1901, a Commonwealth government was established by federation of the six existing self-governing colonies of Great Britain, one of which is the island of Tasmania, which lies off the south coast of Australia across Bass Strait. As in the United States and Canada, this federated form of government involves a distribution of responsibilities between the federal or commonwealth government and the state governments. This is of particular importance in the field of medicine. The provision of medical and health services is a responsibility of the individual states. For many reasons the states have difficulty in discharging this responsibility. Some states are small, while others are very large with inadequate transportation facilities. Some states are densely populated; in some the population is sparse and thinly spread. Some states are wealthy, some have extremely limited resources. Even for a wealthy state, the cost of a complete medical service is beyond its means. Financial aid for many aspects of health and social services must come from federal resources.

Each state has legislation governing hospitals and medical services. While these are not uniform from state to state, in general one can say that all public hospitals are owned and operated by the state in which they exist. Citizens of a state are entitled to public ward hospital services, sometimes without restrictions of any kind, sometimes at a nominal charge graded according to income. In two states there is a full time State Medical Service, operating side by side with private practitioners and private hospitals. All doctors in these states who work in state hospitals are on salary paid by the state and have no private practice. In other states, doctors work in hospitals on a part-time basis as honorary consultants without remuneration or in some cases for a small honorarium. Such doctors rely upon private practice for the greater part of their income. In spite of the availability of free hospital services in state-controlled hospitals, there are still many people who choose to be treated as private patients. They are accommodated in private hospitals of which there are many, some of several hundred beds capacity, operated chiefly by religious bodies of all denominations.

At the end of the war the Commonwealth Labour Government then in power introduced legislation intended to provide a complete national health service. It was strongly opposed by the doctors of Australia. Amongst other objections, they advanced a principle dear to labor unionists and protected by legislation in Australia—namely, that no man should be compelled to work under terms which are unacceptable to him. The debate in the Federal Parliament on this legislation became so intense that the Labour Party decided to go to the country over this and other issues. In the resulting election the Labour Party was defeated and its national health service legislation was abandoned. The present Commonwealth Government subsidizes the cost of medical service and hospital care by giving to each person who carries medical and hospital insurance a sum of money which equals the benefits he receives from his insurance policy. In Australia, as everywhere else in the world, the cost of hospital care has risen enormously until it constitutes by far the largest item in the over-all cost of medical care. For many Australian citizens, the opportunity to be treated as a private patient in a private hospital is the outcome of the assistance afforded under the National Health Scheme. For a premium of two or three shillings per week and with the assistance of the Federal subsidy, a man and his family obtain protection which covers at least 75 per cent of the costs of medical care and hospital services.

As far as hospital and medical services are concerned, Australia is in a transition period. I think everyone will agree that there is room for improvement in the existing systems; which, although they provide a basic service, do so with inequities, inadequacies, and lack of uniformity. It is not easy to predict what form of health service will ultimately evolve. The Labour Party, with its strong socialist leanings, will certainly desire a completely nationalized health service, but the cost may be prohibitive. On the other hand, there is ample evidence that a considerable section of the population is willing and able, with assistance from the National Health Scheme, to pay for private care in private hospitals. It is this group which provides doctors with their income.

The Flying Doctor Service is an interesting and highly successful program which provides medical care to the vast and sparsely populated northern sections of Australia. Seven bases scattered through an area two-thirds the size of the United States provide medical and nursing care to the widely scattered families. Small radio centers, bicycle operated where there is no other source of power, maintain contact with the centers from which they can obtain immediate advice. Special aircraft bring the doctor to the isolated patient or the patient to a hospital at one of these centers. Australians are justly proud of this unique and efficient medical service.

In the discharge of my responsibilities as Sims Commonwealth Professor, I spent two months in Australia. In this time I attended the Annual Meetings of the Australasian College of Surgeons and The Australian Orthopaedic Association. Both of these meetings were held in Sydney. In addition, all of the other state capitals were visited and all of the medical schools except the School of Medical Sciences of the National University at Canberra.

Australia is a young and vigorous country in the midst of an era of unprecedented prosperity. The medical world, including the field of orthopaedic surgery, reflects the vigor of the Australian temperament and their rapidly expanding economy. The Australian Orthopaedic Association is vigorous and growing rapidly. Its founders are still active in the affairs of the Association, and a rapidly growing group of young and able men add great strength to the Association and give assurance that it will continue to grow in strength and importance. There is great interest amongst Australians in the coming Joint Meeting of the Orthopaedic Associations which The American Orthopaedic Association is planning to hold in Washington, D. C., in 1958. It is certain that many will attend.

I expect that there will be a report of the meeting of The Australian Orthopaedic Association in an early number of the British Volume of the Journal.

In travelling to a far-distant country, one cannot help but be impressed by the difference in incidence of disease from that to which we are accustomed. This applies with particular force to orthopaedic surgery which so often is concerned with congenital deformities. We are prone to think that the distribution of congenital deformities throughout the world is uniform and similar to that with which we are familiar. But there are obvious reasons why this is not so. Where a population is stable and the requisite gene of a congenital deformity is present the incidence of that deformity may be very high. Conversely the absence of the gene of a congenital deformity in a stable population results in a low incidence of that particular deformity.

Australia illustrates these principles by several interesting examples. Congenital dislocation of the hip is not common. Anthony McSweeney reviewed the cases which had been treated in the Mater Misericordia Hospital in Brisbane by himself and his senior colleagues, Arthur Meehan and John Lang. There had been only fifty cases in twenty-five years—this in a large hospital with a well organized orthopaedic service. On the other hand, hereditary malformations of the hands and feet are relatively common. So also is osteopetrosis. I personally have never had a case of osteopetrosis under my care. Every hospital in Sydney had several cases currently under treatment.

Paget's disease of bone is much more common in Australia and New Zealand than it is in North America. We do not commonly think of this as an inherited disease. Perhaps it is not, though Prof. Caughey of Dunedin, New Zealand, has gathered some evidence which at least suggests an inherited influence. It is not easy to explain its high incidence in Australia unless hereditary factors play some part or unless it is due to a dietary factor.

Nearly all of the hospitals on the southern and eastern coasts of Australia are troubled by staphylococcal infections which are resistant to antibiotics. For five to eight years following the war, penicillin and other antibiotics eradicated infection. Osteomyelitis, for instance, was controlled and the infection was eradicated without operation. During the last three years control of infection by antibiotics has been lost. The staphylococcus which has escaped from control is a virulent strain and its management is the cause of much concern. Breast abscesses in nursing mothers and neonatal infections arising from the umbilicus are now common. Most orthopaedic surgeons have returned to open drainage of osteomyelitis by incision of the subperiosteal abscess and perforation of the cortex with drill holes. Wound infections in clean operations are common enough to be disturbing.

There are indications that resistant strains of staphylococci are becoming disturbingly common in North America. The time may not be far distant when we shall have to face a problem such as exists in Australia now, unless measures can be devised to control the situation. The time may be opportune to return to the use of antiseptics. They certainly transformed the septic hospitals of Lister's day to the germ-free hospital of the aseptic era of surgery.

A chronic non-specific synovitis of the knee is common in Australia. It occurs in children and young adults, most frequently in females. Most often only one knee is involved, occasionally both knees and sometimes other joints are involved. The joint is swollen, warm, and slightly thickened. The extremes of movement are limited. There is moderate pain and tenderness. The sedimentation rate usually is elevated; the temperature usually is normal. It runs a prolonged course and tends to subside spontaneously. In growing children there is overgrowth in length of the involved extremity. It simulates synovial tuberculosis of the knee but it is not, because the skin test is negative and the fluid does not yield tubercle bacilli on culture

or guinea-pig inoculation. The synovial fluid is not grossly abnormal and organisms are not grown from it. It does not progress to rheumatoid arthritis or Still's disease. Biopsy of the synovial membrane has not provided any specific picture.

I have seen a few such cases in Canada, but they have been very rare. There are many cases in Australia.

In Adelaide I had the pleasure of meeting two promising young orthopaedic surgeons, of interest to all of us because of the contributions of their fathers to orthopaedic surgery. One was W. J. Betts whose father, the late L. O. Betts, first demonstrated that Morton's metatarsalgia is due to a plantar digital neuroma. He was not able to determine the mechanism whereby the neuroma developed but he did demonstrate that resection of the involved segment of the fourth digital nerve instantly and permanently cured the condition. Nissen has since popularized the concept of Betts so that treatment by resection of the nerve has been widely accepted. The second young orthopaedic surgeon was N. J. Royle, whose father, N. D. Royle, with John Hunter opened the field of surgery of the sympathetic nervous system by their experiments on muscle tone which led them to the conclusion that tone was the result of impulses conveyed by sympathetic nerves and that spastic paralysis, which is characterized by excessive muscle tone, might be improved by section of the sympathetic trunks.

I had the pleasure also of meeting H. C. Trumble of Melbourne who first advocated fusion of the hip by an ischiofemoral graft. Trumble is a general surgeon whose catholic interests range from neurosurgery through gastro-intestinal surgery to orthopaedic surgery. He no longer is interested in fusing hips by any method. But his contribution has provided us with one of the best approaches and one of the best methods for extra-articular arthrodesis of the hip.

While I was in Perth, the capital of Western Australia, an unique event occurred. There is the fine University of Western Australia in Perth but there is no medical school, although one is much needed. A campaign was organized to raise £400,000 by *public subscription* to found a medical school. The campaign was directed by the medical profession through the Western Australia Division of the British Medical Association. The opening ceremony occurred the day I left, in the undercroft of the University, where there was a public gathering of the medical profession in their academic robes to state the need for a medical school and to dedicate themselves to the task of raising the necessary funds by public subscription. I have since learned that the objective of £400,000 ($1,000,000) has been oversubscribed. This seemed to me an unique event—the medical profession willing to bear the burden of conducting a campaign to raise funds to found a medical school and the general public willing to subscribe generously to an object which usually is thought to be the responsibility of government. West Australia is a huge state but is thinly populated (640,000) and Perth is relatively a small city (349,000 population).

Some highlights of the program of The Australian Orthopaedic Association were the following: The Address of the President, Tom King of Melbourne, on Low-Back Pain and Intervertebral-Disc Lesions—a thoughtful discussion based upon much clinical experience supported by postmortem study of the lumbosacral region and its anomalies. A technique for visualizing carpal injuries by radiography was reported by Joseph Jens. This was air arthrography of the carpal and radiocarpal joints secured by injection of the air into the radiocarpal joint from whence it spread into all the intercarpal joints. This and the use of magnified radiographs (king-sized films) often clarified minor carpal injuries. Acute osteomyelitis in children, a report by W. Gilmour, emphasized the present failure of penicillin to control staphylococcal infection. Osteotomy of the hip with spline fixation by R. Hodgkinson was one of several presentations which stressed the merits of McMurray's osteotomy. W. D. Sturrock reported on the value of quadricepsplasty. N. J. Royle presented two cases of tennis elbow with calcification in the tendon of origin of the extensor muscles of the forearm which stimulated much discussion, some of it from members of the Association who had suffered from this disease. D. W. Parker of Hobart related his experience with the establishment of a bone bank in Tasmania where he is the senior orthopaedic surgeon for the government of Tasmania.

At the Australasian College of Surgeons, O. W. Leitch reported sixteen cases of painful knee (mostly due to osteo-arthritis though one was due to tuberculosis) greatly benefited by neurectomy. His success was due to careful anatomical studies and the section of all sensory branches of the knee. My interest in neurectomy has been renewed by his work and experience.

It is sad to have to record the tragic death in late November of two members of The Australian Orthopaedic Association, Arthur Meehan and A. R. Murray of Brisbane, who were killed by a mentally deranged patient.

Proceedings

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Eleventh Annual Meeting of the American Society for Surgery of the Hand was held in Chicago under the presidency of Dr. S. Benjamin Fowler of Nashville, Tennessee.

On January 27, 1956, the following papers were read.

Osteogenic Sarcoma in the Hand. Dr. Robert E. Carroll [1] reviewed ten cases of osteogenic sarcoma in the hand. Eight of these cases had come from sources other than his own material, seven of these eight having been previously presented in the literature. The author had been able to obtain more recent data on two of the previously reported cases.

Difficulty in differential diagnosis was emphasized, the author pointing out that it is sometimes hard to differentiate between osteogenic sarcoma and myositis ossificans. The cases were also studied with reference to any factors which might have constituted a predisposing etiology. In the largest group, six cases in all, there appeared to have been no complicating factors in the development of the tumor other than involvement of the bone itself. In the second group, in which there were two cases, it appeared that the predisposing etiology had been ionizing radiation. In the third group, the condition was described as multifocal because other osteogenic sarcomata were present in the patients. In one of the two patients in this group, the osteogenic sarcoma had arisen in the metacarpal; this patient had altered bone metabolism due to osteitis deformans. In the other patient in this group, the tumor was probably of metastatic origin.

In this series, the age and sex of the patients seemed to have no statistical significance. The tumors appeared to have occurred in the phalanges about as often as in the metacarpals. It was felt by the author that trauma probably had not played any role as a predisposing factor.

There was one patient in whom two metacarpals had been resected as a result of osteogenic sarcoma involving one of the metacarpals. This patient was living and well seven years after the operation. Another patient, whose case had been previously reported by Copeland, was said to have been alive and well ten years following a local resection. In a third very dramatic case the gradual development of a tumor in the terminal phalanx had been demonstrated by several roentgenograms. This patient was said to have been alive and well six and one-half years following amputation of the fingers by metacarpal resection.

When the tumor arises in the phalanx or metacarpal, the author feels that local resection can be carried out as the initial treatment with a more favorable prognosis than that for osteogenic sarcoma located at more proximal sites. This treatment leaves the hand a functional unit. While the series was too small to allow the author to make any real statistical analysis, in general it was felt that in cases of osteogenic sarcoma arising in the hand the patient has a greater than 50 per cent chance of surviving more than five years following local resection.

Dr. Robert H. Clifford [2], in discussing Dr. Carroll's paper, emphasized the need for early recognition of the disease and stated that if one could recognize the clinical entity early, one could probably offer a good prognosis. Dr. Clifford presented a case of a patient who had lived seven years following local resection for osteogenic sarcoma.

Dr. Henry C. Marble [3] disagreed with Dr. Carroll's rather conservative approach to this malignant disease. He was skeptical of the diagnosis of osteogenic sarcoma in those patients who had lived a long period of time following an operation which had consisted merely in local amputation of the finger and metacarpal. Dr. Marble emphasized the difficulty in distinguishing pathologically between callus which has developed following a recent fracture and osteogenic sarcoma.

Dr. Leo Mayer [4] agreed with Dr. Marble concerning the difficulty of diagnosing osteogenic sarcoma of the hand and presented a case which illustrated this difficulty. He felt that if the diagnosis of a large tumor of the metacarpal is doubtful, a conservative operation should be tried before amputation is done. He agreed with Dr. Carroll's emphasis upon the importance of conservative methods.

Use of Single Large Iliac-Bone Graft to Replace Multiple Metacarpal Loss. Dr. Julian M. Bruner [5] presented two cases, beautifully illustrated, in which single large iliac-bone grafts had been used, with good results, to restore hands in which three or four of the metacarpals had been destroyed. It was Dr. Bruner's feeling that when multiple metacarpals have been lost, a single block of iliac bone makes a

[1] 180 Fort Washington Avenue, New York, N. Y.
[2] Henry Ford Hospital, Detroit, Michigan.
[3] 270 Commonwealth Avenue, Boston, Massachusetts.
[4] 1150 Fifth Avenue, New York, N. Y.
[5] 1005 Bankers Trust Building, Des Moines, Iowa.

more stable support for the distal portion of the metacarpals and phalanges than does any other type of graft. He feels that by this method one can more simply repair extensive bone loss, and he prefers this method to the use of multiple pieces of iliac bone, with individual metacarpal reconstruction.

In the first of the two cases presented, the bases of the proximal phalanges had been fused into the distal end of the bone graft at an angle of 135 degrees; the distal end of the metacarpal and the base of the proximal phalanx had been destroyed. The extensor tendons had not needed to be replaced since lumbrical and interosseus action extended the distal two joints. The second case was one of a gunshot wound with extensive loss of skin, destruction of the extensor tendons of the dorsum of the hand, and destruction of the second, third, and fourth metacarpal bones. The procedures had been performed in stages, the initial treatment consisting in débridement, followed by the application of an abdominal pedicle flap fourteen days later. A large iliac-bone graft had then been anchored into the carpal bones proximally. The last stage had consisted in the insertion of extensor-tendon grafts.

The author emphasized that no attempt should be made to restore the complete length of the damaged metacarpals. He also emphasized the need for placing the extensor-tendon grafts with the proper amount of tension. The author had used the full thickness of the ilium for the grafts.

Dr. Richard E. Stauffer [6] complimented Dr. Bruner on his fine paper and re-emphasized the need for proper alignment of the metacarpals, pointing out that unless this re-position is maintained at the time of bone-grafting, scissoring of one finger across the other will develop.

Dr. George S. Phalen [7] pointed out that the functional end result in these two patients had been excellent and re-emphasized the need for obtaining the proper amount of tension in placing the extensor-tendon grafts.

Spontaneous Rupture of the Extensor Tendons of the Hand Associated with Rheumatoid Arthritis. Dr. L. Ramsay Straub [8] and Dr. Edward H. Wilson [9] presented a group of five female patients who had suffered spontaneous rupture of the fourth or fifth or of both extensor tendons at the point of passage around the distal end of the ulna. In all of these patients, the distal end of the ulna had been found, by means of roentgenograms, to have subluxated dorsally. In every case there was a history of past or present rheumatoid arthritis and of varying degrees of synovial reaction involving the extensor-tendon sheath. Three of the patients had come to operation, and in each of these patients the tendon had been found to be attenuated and frayed at the point of rupture where it passed around the distal end of the ulna. The three patients who were subjected to surgery had responded well. In each case the distal portions of the separated tendons had been attached to the nearest intact slip of the extensor digitorum communis. In addition to repair of the tendons, the authors recommended resection of the lower end of the ulna. It was the authors' opinion that the occurrence of the lesion in the arthritic hand is not rare, but that in this group of patients it was probably overlooked because of the severity of the other deformities and complaints. It was felt that the lesions described resulted from: (1) attritional change in the tendon due to rheumatoid synovitis, (2) attrition due to age, and (3) increased wear and tear due to prominence of the distal end of the ulna.

Dr. S. Benjamin Fowler [10], in discussing the paper, complimented the authors on the simplicity of their operation and on their approach to the problem.

Dr. Lot D. Howard, Jr.[11] pointed out that in rheumatoid arthritis with joint involvement, one could expect sudden rupture of a tendon as a result of friction against the involved joint accompanied by elongation and then dissolution as the tendon stretched; one might also find actual invasion of the tendon itself by granulation tissue. Dr. Howard emphasized the fact that synovectomy is an important procedure, for, if performed early, it might prevent the subsequent dissolution and rupture of tendons which become involved secondary to the synovitis.

In addition to the technique of repair suggested by the authors, the discussor also mentioned the use of tendon transfer.

Dr. Sterling Bunnell [12] complimented the authors on their paper and re-emphasized the role which granulation tissue plays in the dissolution of ligaments and tendons in rheumatoid arthritis.

Dr. Leo Mayer [4] pointed out that, while it is necessary to repair extensor tendons under tension, one should still remember that if too much tension is used in inserting the tendon transplant or graft, one can do damage to the muscle fibers and actually produce degeneration in the muscle.

Anatomy of the Hand. Dr. Ernest W. Lampe [13] gave a very interesting lecture with reference to the

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anatomy of the wrist—both the volar and dorsal aspects. He emphasized the important structures and their relationship to one another and pointed out ways in which one could associate the positions which each of these structures occupied at various levels.

Colles' Fracture. Dr. Henry C. Marble [2] discussed the poor functional results that follow Colles' fracture. Every hand surgeon must frequently encounter a stiff, frozen, painful, and essentially useless hand that has resulted from a simple Colles' fracture. The statistics vary from 4 to 10 per cent of all cases.

Too much attention is directed in our writing and in our teaching to the injury to the bone, to the necessity for perfect anatomical re-position, and to the obtaining of a good roentgenographic picture. Far too little time is spent considering the injury to the soft parts, the swelling and the harmful results of the swelling, the extravasation of fluid, the injury to the pronator quadratus, and the pressure exerted on the tendons, nerves, and blood vessels.

On the palmar surface of the wrist there is a bone and fascial envelope that can and often does, as part of Colles' fracture, retain increasing amounts of blood and extracellular fluids. As a result there may develop a condition at the wrist which is the exact counterpart of Volkmann's contracture at the elbow.

This condition is more insidious and more difficult to recognize than a true Volkmann's contracture. The warning signs are less marked, and the symptoms are less well defined. The author feels that the presence of this condition rather than inadequate reduction is the primary cause of stiffness.

The author believes that we should revise our thinking and consider the soft-part injury and its management first and the problem of holding perfect bone reduction second. Most of the irreparable damage occurs in the first few days and, in order to prevent this, early attention must be maintained until the danger period is over.

Once the fracture is reduced, primary attention must be given to the reduction of the swelling and to the establishment of active motion (a swollen hand cannot move), while secondary attention must be given to splints and splinting.

It was stressed by the author that hand surgeons should work for a good functional hand with a fine range of motion even at the expense of a less satisfactory roentgenographic picture.

Dr. Michael L. Mason [14] pointed out that the surgeon who deals with injuries to the hand has constantly to keep in mind that his concern is first with function, next with anatomical restoration, and last with cosmetic appearance. The roentgenogram, by means of which perfectly visible signs are produced of the bones and their alignment, is not matched by any record of the concomitant damage to soft parts and yet this damage is often of considerably more import than the bone injury. It is important that all the effects of injury be corrected as soon as possible, that bleeding be stopped, dead spaces obliterated, and tissues brought back into as normal a relationship as is possible. Dr. Mason stressed the importance of a proper compression dressing. Pressure must be evenly distributed over an area which extends well above and below the site of injury, and it must be applied without constriction.

Dr. Joseph L. Posch [15] discussed rupture of the extensor pollicis longus tendon following Colles' fracture and reported four cases. The incidence of this complication is roughly one per 250 cases of Colles' fracture. Sixty per cent of the reported cases have been found in females and 40 per cent in males; 80 per cent of the cases have involved the right hand. The tendon rupture may occur from twelve days to seven years following the fracture, although two to seven months seems to be the average time. The condition can occur in patients of any age, but it is more common in patients over the age of thirty. The most widely accepted theory as to etiology is that interference with the blood supply of the tendon occurs at the time of wrist fracture and that this is followed by aseptic necrosis and eventual rupture of the tendon.

The Carpal-Tunnel Syndrome. Dr. Bland W. Cannon [16] presented twenty-two cases of tardy median palsy. In eleven of these cases correction was obtained by division of the transverse carpal ligament. Many factors, such as external trauma, bone deformity, arthritis, and acromegaly, seemingly contributed to the pathogenesis of this entity. It was the author's opinion that nocturnal or early-morning swelling of the hands was the most important factor in initiating the median-nerve compression. This swelling and numbness and paraesthesia in the hand comprise the symptom complex of "waking numbness", a condition which the author suggests is due to intermittent vascular compression at the pectoral level. "Waking numbness" was characteristically present in the author's cases and appeared as the precursor of the median-nerve constriction found within the carpal tunnel.

Dr. J. Leonard Goldner [17] discussed vascular compression at the pectoral level. He feels that *local* vascular compression is a tenable explanation of the condition, but that distant vascular compression is not. His experience with carpal-tunnel syndrome indicates that in the majority of patients a specific or presumptive cause can be determined. He feels that more evidence and more experience are necessary before this theory can be accepted.

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DR. SUMNER L. KOCH [18] discussed the type of pain which occurs in the typical case of carpal-tunnel syndrome and compared this syndrome with the atypical acroparaesthesia syndrome which has been attributed to neuromuscular compression at the cervico-axillary junction. He feels that the two syndromes are not the same and that the underlying pathology is different.

Congenital Deformities of the Hand. DR. HERBERT CONWAY [19] and DR. JOHN BOWE [20] presented a review of their experience with upper-extremity congenital anomalies at the New York Hospital-Cornell Medical Center over a period of twenty-two years. The review covered 164 cases, and representative cases were illustrated. Pathogenesis and surgical treatment were discussed. Among the live babies born in the New York Hospital there had been an incidence of anomalies of the upper extremity of one in 626. Thirty-one per cent of these babies had been born prematurely. The most important single factor in the production of the anomalies was thought to be heredity, for the pattern of inheritance of the deformities approached Mendelian expectancy. The association of certain vitamin deficiencies was pointed out, and it was mentioned that in experimental studies it had been shown that in strains predisposed toward anomaly production, vitamin deficiency will cause a much higher incidence of anomalies. Many interesting slides were shown, and treatment was briefly discussed. It was pointed out by the authors that therapy must be individualized, that the long-range plan must be carefully mapped out with anticipation of growth needs and with the careful placing of the incision lines.

DR. JEROME P. WEBSTER [21] discussed the part that heredity plays in the different types of anomalies.

DR. WILLIAM H. FRACKELTON [22] discussed the treatment of syndactylism. He feels that treatment should be undertaken early if there is bone fixation of the fingers. Because of the requirements of circulation, it is usually impossible or unwise to fix more than one side of a digit at one time.

Neurovascular Pedicle Transfer of Tissue in Reconstructive Surgery of the Hand. DR. J. WILLIAM LITTLER [23] discussed the use of a neurovascular pedicle graft as a method of tissue transfer which permits a wide range of freedom without jeopardizing either circulation or sensation. The method is most applicable to the hand, for the neurovascular system of one part of the hand may be easily transferred to another part. When gross loss of the coverage and of the deeper structures of the forearm and hand are encountered, a direct pedicle flap, generally from the abdomen, is required for resurfacing. The purpose of this paper was to describe the use of local composite tissue, isolated and transferred on a neurovascular pedicle graft, in the restoration of vital areas rendered anaesthetic through irreparable nerve or soft-tissue damage, in the treatment of defects requiring limited pedicle-skin coverage, and in the reconstruction of a thumb through the transfer of a digit. Slides were presented showing illustrative cases. In one case sensation had been restored to the index finger by means of a transfer from the ring finger. In another case reconstruction of the thumb had been done.

DR. DON L. EYLER [24] congratulated the speaker on his excellent technique and results. He pointed out that the success or failure of this type of composite-tissue transplant depends upon the integrity of the arteriovenous system, especially on the venous return. If there is congestion of one part or of all of the transplant, failure will occur.

DR. RADFORD C. TANZER [25] said that the neurovascular pedicle graft is a rather dramatic example of a group of methods which, heretofore used only sporadically because of the hazards inherent in their use, have become feasible through the application of a number of refined techniques developed during World War II and the ensuing years. He feels that Dr. Littler has developed successfully a method by which thumb reconstruction may be carried out, not only without the necessity of recourse to supplementary tissue for skin coverage, but with the added virtue of permitting the use of digits not immediately adjacent without the application of pedicled-carrier flaps. He stressed the necessity for increased precision and delicacy of execution in order to obtain and maintain an arteriovenous balance sufficient to support tissue life and to ensure nerve function. He concluded that for the present, it would perhaps be well if this ingenious operation was done only by surgeons possessing wide experience.

The Surgical, Social, and Economic Aspects of a Unit Hand Injury. DR. WILLIAM METCALF [26] and DR. WILLIAM WHALEN [27] analyzed a series of so-called minor hand injuries. Two hundred and forty cases of injury to, or amputation of, a distal phalanx were studied. The causes and agents of the accidents were analyzed.

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[22] 324 East Wisconsin Avenue, Milwaukee, Wisconsin.
[23] 16 East 90th Street, New York, N. Y.
[24] 1921 Broad Street, Nashville, Tennessee.
[25] Hitchcock Clinic, Hanover, New Hampshire.
[26] 1085 Park Avenue, New York, N. Y.
[27] 111 East 61st Street, New York, N. Y.

The patients were cared for on an ambulatory status in an emergency operating room. General operating-room conditions were maintained with some minor modifications. Digital-nerve block was the anaesthesia of choice for all patients except for a few treated early in the series and except for those with psychic disturbances due to injury or youthfulness; for the latter patients general anaesthesia was used. A tourniquet on the arm or on the finger was never used, and antibiotics were not administered.

Reconstruction of the finger tip was always the goal, as much of the pulp and fingernail as possible being saved. Amputation as an expedient means of obtaining closure of the wound was never done. Only when there had been sharp transverse amputation proximal enough to divide the insertion of the profundus tendon or to go through the distal joint was the remaining distal phalangeal bone removed and the condyles of the middle phalanx rongeured off in order to allow direct suture of the skin flaps. Reconstruction was always done in crushed finger tips with multiple flat formation, in fingers in which sharp amputation beyond the joint had occurred leaving a bridge of tissue and a neurovascular pedicle, in fingers with flap avulsion of nail matrix and pulp with exposure of bone, and in fingers in which there was a sharp, long, oblique amputation of half the finger tip.

The treatment of the patients on an ambulatory basis simplified postoperative care and was eminently satisfactory. The average number of office visits required was only six and the average time lost from work was only twenty-six calendar days. The authors felt that judicious modification of the previously established fairly rigid conditions for reparative hand surgery may be applied without compromising the surgical results.

Dr. Darrel T. Shaw [28] felt that the authors have employed practical surgical judgment by adapting good surgical principles to an emergency-room and out-patient routine. By encouraging out-patient status and early return to work, they have practiced good psychology and have minimized the emotional trauma experienced by the patient with an injured hand. An important by-product has been an earlier return of hand function.

Dr. Raymond M. Curtis [29] stated that the excellent results which these two authors have obtained in this series of cases certainly would suggest that this type of injury can be treated on an emergency-room basis. If one carries out a meticulous technique of débridement and cleansing, satisfactory results can be expected. He preferred, however, the use of antibiotics and a tourniquet. Careful attention must be given to the volar digital nerves if they have been divided in the avulsion or amputation, for if the terminal portion of the nerve is allowed to remain at the tip of the finger and become involved in scar as the neuroma forms, a considerable amount of disability will follow. Conversely, if the cut end of the digital nerve is allowed to retract back into normal subcutaneous tissue following a resection of a portion of the nerve, less disability will be experienced from the resultant neuroma.

The annual Members, Dinners was held on the evening of January 27, 1956, at the Palmer House.

The Clinical Program, for members and invited guests, was presented on the morning of January 28, 1956, at the Palmer House. The following papers were read:

Perilunar Dislocations. Dr. Carruth J. Wagner [30] presented a complete discussion of perilunar dislocations. He attempted to demonstrate that most fractures and dislocations of the carpus follow a sequential pattern. The primary loss of relationship occurs at the junction of the fixed axis of the hand with that of the forearm—the capitate-lunate joint—resulting in a perilunar dislocation of the wrist.

The additional manifestations of the injury will vary, depending upon the direction and power of the deforming force, the anatomical variations in the various carpal bones, the ligamentous structures, and the state of the muscles at the time the injury occurs.

The result of treatment usually can be predicted by evaluating the individual injury in terms of the following two factors: the presence of associated fractures, particularly of the navicular, and the exactness of the reduction achieved by closed methods.

Dr. E. B. Kaplan [31] thought that this was a most excellent presentation and that it certainly cleared up a number of points that had formerly seemed obscure. It is extremely important to take into consideration the blood supply to these bones. There are two ligaments that are of great importance in the preservation of the blood supply of the navicular and lunate. In an open operation it is very important to avoid this area as much as possible because destruction of these two ligaments is probably responsible for aseptic necrosis.

What Is a Good Tendon Result? Dr. Robert H. Clifford [2] discussed the confusion of terms which prevails in connection with this matter in a very entertaining fashion. He pointed out the difference in meaning to various authors of such terms as *excellent, good,* and *poor*. Sixteen articles on tendon surgery had been reviewed with particular reference to the exact meaning of the phrase "a good tendon result."

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In nine of these articles no criterion whatever had been given, and in the others there had been a great variation in the criteria.

The author submitted a scheme of criteria and classification which was based, not on a fixed formula of finger position or of degrees of flexion, but on the relation of the injured part to the uninjured opposite member. It was suggested that the results be stated in terms of restored function rather than in terms of lost function. It was pointed out that there is a great difference in the amount of flexion that can be obtained by different individuals. He feels that only by such a system can the correct appraisal of restored function be accomplished.

Dr. Joseph H. Boyes [32] and Dr. J. Edward Flynn [33] discussed this paper and both agreed that there is need for clarification of terminology.

Symptoms Caused by Extensor Indicis Propius Muscle. Dr. Richard S. Oakey, Jr.[34] presented two cases of anomalous muscles in the dorsum of the hand. In each case the lesion had been diagnosed clinically as a ganglion, but at operation the abnormal muscle had been found. In both cases the muscles had seemed to originate at the dorsal carpal ligament and to insert into the base of the index finger. Traction on the muscle bundle had been found to elevate the index finger. At the time of surgery, the muscle had not been removed but an incision had been made into the dorsal carpal ligament in order to prevent binding of the muscle. In each case relief of symptoms had been obtained. The follow-up had not been prolonged, being three months in one case and nine months in the other.

The paper was discussed informally by several of the members. Dr. Sterling Bunnell [12] pointed out that these muscles occur in amphibians and reptiles and that the anomaly is an atavism.

Late Treatment for Rupture of the Extensor Tendons at the Proximal and Distal Interphalangeal Joints. Dr. Darrel T. Shaw [28] presented four illustrative cases: one of rupture of the central slip of the extensor tendon over the proximal interphalangeal joint, one of rupture of the extensor tendon over the distal joint, and two of severe flexion deformities of the proximal interphalangeal joints of all the fingers.

Because of the difficulty experienced in maintaining extension of the finger joints by means of external splints after late repair for rupture of the extensor tendons, internal splinting by means of Kirschner wire passed through the finger joints had been used. Problems of skin maceration, incomplete tendon relaxation and excessive external pressure had been avoided, and it had been possible to maintain a joint position which resulted in better tendon union and better end-results. Internal fixation by means of wires passed obliquely and laterally across the joint had been done at the time of surgical repair of the extensor tendon. Surgical repair had consisted in resection of the redundant scar and tendon over the joint and end-to-end suture. Internal splinting had been maintained from four to six weeks. In order to reduce the tension on the extensor tendon which occurs when repair is done over the distal joint, the lateral bands had been relaxed by the proximal interphalangeal joint being held in approximately 45 degrees of flexion by means of crisscrossed adhesive or collodion strip dressings. The lateral bands had been lengthened if they were found contracted at the time the central slip was repaired over the proximal interphalangeal joint.

This paper inspired much discussion and many comments from the audience. Internal wire fixation was generally approved. Several different techniques of inserting the wires were mentioned. It was generally agreed that a good result is difficult to obtain in this type of injury.

Applied Anatomy of the Hand. Dr. Ernest W. Lampe [13] discussed the anatomy of the hand with particular reference to the intrinsic muscles and the extensor apparatus. His remarks were illustrated by crayon drawings made as the talk progressed.

The next Annual Meeting of the American Society for Surgery of the Hand will be held in Chicago, Illinois, on January 25, 1957.

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THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

Scientific Sessions
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The Use of Cutis as an Interposing Membrane in Arthroplasty of the Knee. Dr. Joseph E. Brown [1], Dr. W. H. McGraw [2], and Dr. Darrel T. Shaw [3] reported four cases in which cutis had been used as an interposing membrane in arthroplasty of the knee. The follow-up periods in these cases had ranged from two and one-half to six years. In all the patients good results had been obtained.

The graft had been removed by means of a dermatome from the lateral aspects of the thorax or abdomen or from the proximal-lateral aspect of the thigh or buttock. The first step had been to cut a full-thickness skin graft which was left attached to the margin of the drum. The blade had then been adjusted and the full-thickness skin graft had been split, the superficial portion of the graft being replaced in its original location and the deeper fragment being taken as the cutis graft. The cutis had been applied to the reconstructed distal portion of the femur under normal tension, its superficial side being placed against the bone. It was held in place by pull-out wire sutures.

The advantages of cutis over fascia lata and foreign-body membranes are its availability in an abundant supply; its strength, toughness, and elasticity, which permits it to conform to an irregular surface; its workability; and its lack of significant foreign-body reaction.

The fate of the cutis membrane in the weight-bearing area is unknown.

Intramedullary Wire Fixation of Mallet Finger. Dr. S. Ward Casscells [4] and Dr. Theodore B. Strange [5] reported their results in the treatment of mallet finger by intramedullary fixation. Because of technical difficulties and because of three instances of permanent painful limitation of motion of the proximal interphalangeal joint following use of the Pratt technique, they had modified this technique. Instead of both interphalangeal joints being immobilized by wire, a .045-inch Kirschner wire had been drilled across the distal joint, which was thus held in maximal hyperextension, and the proximal joint had been subsequently immobilized in 60 degrees of flexion by means of a skin-tight plaster. More hyperextension of the distal joint could be obtained by this method than by the other. Measurement on an articulated skeleton revealed that 30 degrees of hyperextension from a neutral position had resulted in a 1.5-millimeter shortening of the tendon. The wires had been removed after from three to five weeks.

Twenty fingers of nineteen patients had been treated by this method. Of these patients, ten had been treated within one week of injury, two at one month, one at three months, and one at six months. The remaining five patients had been treated between eight and twenty-five days after the injury. In four of these patients there had been an associated fracture of the proximal tip of the distal phalanx. The results had been as follows: *good* in nine fingers with full extension and only slight or no loss of flexion; *fair* in seven with loss of 5 to 10 degrees of extension and often loss of about 15 degrees of flexion; and *poor* in four. In three of the fingers with *poor* results the wire crossed the proximal joint. *Good* and *fair* results respectively had been obtained in the two patients treated three and six months after injury; in these cases immobilization without repair of the tendon had been the only treatment. The authors attributed their success to the fact that 20 to 30 degrees of hyperextension can be obtained by this method.

The authors pointed out that stiffness of the distal joint produces surprisingly little disability. The complications encountered in this series included intolerance to cold for months after treatment ("a mild or borderline causalgia") and a mild transitory loss of tactile sensation.

Dr. Sterling Bunnell [6] discussed this paper. He stated that he and Dr. Pratt had used the latter's technique in fifty-one cases with satisfactory results. Recently they have used a guide which assures proper placement of the wire. In patients over ten years of age, a stainless-steel pull-out wire, spliced into the tendon and passed through the nail, is used in conjunction with Kirschner-wire fixation in order to shorten the tendon which may or may not be sectioned. When the tendon is found adherent to the middle phalanx, slippery fascia or a piece of polythene is placed beneath it. The latter is removed after one month. The results obtained by Dr. Bunnell and Dr. Pratt have been good, although frequently the range of motion obtained has not been complete.

Fractures of the Distal Radial Shaft. Dr. Jack C. Hughston [7] reported that closed fractures of the radial shaft at the junction of the middle and distal thirds, occurring in association with fractures of

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[6] 516 Sutter Street, San Francisco, California.
[7] 1316 13th Avenue, Columbus, Georgia.

the ulna, are infrequent. The forty-one cases reported in this paper were gathered and studied by the members of the Piedmont Orthopedic Society. Thirty-eight patients had been treated by closed reduction. In three of these patients the results had been satisfactory and in thirty-five they had been unsatisfactory. Three patients had been treated by open reduction and internal fixation, the results being satisfactory in two and unsatisfactory in one. The author reviewed the various methods employed and pointed out features which the Society considered to be mistakes in management. The four factors thought to be the major causes of postreduction deformity were: (1) weight of the hand, (2) pull of the pronator quadratus, (3) pull of the brachioradialis, and (4) the deforming pull of the abductors and extensors of the thumb.

The final conclusion was that fractures of the distal third of the radial shaft are difficult to treat successfully by closed reduction. Open anatomical reduction, with rigid and secure internal fixation (in order to prevent postoperative subluxation of the distal radio-ulnar joint) appears to be the treatment of choice if the patient is operated upon immediately or very early. For patients operated upon three to four weeks after fracture, serious consideration should be given to resection of the distal portion of the ulna and to bone-grafting of the radius. For patients operated upon later than four weeks, bone-grafting of the radius and resection of the distal portion of the ulna appears to be necessary if restoration of good function is to be obtained.

Treatment of Grade-IV Fracture-Dislocation of the Hip. Dr. Garrett Pipkin [8] presented an excellent analysis of the results obtained in twenty-five patients with dislocation of the hip complicated by fracture of the femoral head or neck (Stewart's Grade IV). The series was composed of patients treated by sixteen experienced orthopaedic surgeons. By pooling these rare cases a larger series and more significant analysis was possible. The length of follow-up had been from six months to eighteen years. Serial roentgenograms and case histories, including end-result evaluation by the contributing surgeon, comprise the data.

In the group with capital fractures the results seemed to depend in part upon the promptness of reduction of the dislocation. The capital fragments united if reduction of the dislocation had been prompt, regardless of the orientation of the fragments but provided that they were in contact and that plaster fixation or traction was used.

In closed manipulative reduction there is danger of fracturing of the neck of the femur (two cases in this series). To avoid this, Stimson's gravitational method of reduction is suggested. When open reduction is necessary, the obstructing fragment is either removed or fixed to the main fragment. In the author's series closed reduction gave better results than open reduction; there was less trauma and fewer degenerative changes developed later.

Fibrous or bony ankylosis may develop spontaneously within three to five years, the latter as a result of late calcification of the capsule. In the author's series this complication occurred in three of the hips in which good functional results were obtained.

In cases of fracture of the femoral neck, it is recommended that pinning be done following internal fixation of the capital fragments or of the rim of the acetabulum. The dislocation is reduced at open operation.

In four of the five hips treated by insertion of an endoprosthesis, a good functional result was obtained.

In this series of patients, treated in accordance with the principles outlined, there were fifteen good or serviceable results and ten failures.

Dr. Robert L. Patterson [9] felt that the chances for a good hip after this severe injury were small, that in a high proportion of cases avascular necrosis or degenerative changes were to be expected, and that, whenever possible, prompt closed reduction should be attempted.

Dr. Marcus Stewart [10] stated that delay increased the chance of manipulative fracture. He indicated that evaluation of the result should not be made until eighteen to twenty-four months after operation.

The Management of Long-Bone Fractures in Paraplegic Patients. Dr. Sidney N. Eichenholtz [11] presented a relatively small series of unselected paraplegic patients with fractures of the long bones. In this series there was a high incidence of disastrous complications following treatment procedures which would have been acceptable for patients who were not paraplegic. The paraplegic patients showed poor local resistance to pressure, trauma, and infection. Hematoma formation was common and healing powers were diminished; the presence of associated bone atrophy made it almost impossible to obtain rigid internal fixation of the fractures.

In the treatment of these patients, prime consideration should be given to the general condition of the patient and to the prevention of decubitus ulcers and urinary stasis. Well padded, removable plaster shells are recommended for immobilization of the fracture; use of a Stryker frame will facilitate the necessary frequent inspection of the skin beneath the plaster shells.

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Dr. Marcus Stewart [10] discussed the paper. He agreed that the use of skin traction is disastrous. Dr. Stewart reported two cases of his own and discussed the treatment of paraplegics about to undergo operations in which wide-spectrum antibiotics are to be used. He said that supportive systemic treatment should be instituted early, that deficiencies in the ratio of serum albumin to serum globulin should be corrected, and that supplemental vitamin therapy, especially vitamin C, seemed indicated.

Dr. Robert Lee Patterson [9] agreed that the use of accepted methods for the treatment of fractures of the lower extremities gave disastrous results when used in the treatment of such fractures in paraplegic patients. He thought that the treatment of fractures of the long bones in paraplegic patients was as much a medical problem as an orthopaedic problem.

The Use of the Bent Screw Plate in Fractures of the Upper and Lower End of the Femur. Dr. John H. Moe [12] gave a brief history of the development of nails and plates satisfactory for the fixation of an intertrochanteric fracture. The Jewett nail, Moore blade plate, and Neufeld's V blade plate were developed in the early 1940's. At about this time the author started using a bent screw plate for internal fixation of the intertrochanteric fracture. A few years later he began the use of this plate for internal fixation of condylar and supracondylar fractures. The author believes the average intertrochanteric fracture is most efficiently treated by the Jewett or Neufeld nail plate. However, there may be an occasional case of a marked comminution, external-rotation, or other deformity which can be fixed more efficiently by means of the screw plate. One must be aware of the potential deformities which may occur, especially shortening and varus. He stated that the subtrochanteric fracture is much more easily fixed by the screw plate than by the Jewett, Neufeld, or Moore plate, but in the presence of osteoporotic bone, external protection is necessary regardless of the type of internal fixation.

High-femoral-osteotomy fragments have been fixed successfully by the use of the screw plate. In a paper read before The Academy in 1941, the author reported forty such operations. He has also used the bent plate in the fixation of ununited femoral-neck fractures treated previously by combined osteotomy and bone grafting. In a similar manner the plate has been used in fresh femoral-neck fractures treated by a primary osteotomy. Ten such operations have been performed, but the use of this operation has been discontinued because the degree of non-union and avascular necrosis remains unchanged.

The femoral fractures may be condylar, supracondylar, or T-type. Until recently, the suggested treatment has been conservative, with acceptance of the inevitable limitation of knee motion which follows prolonged immobilization and of frequent malunion. The transverse supracondylar fracture can be held by two Rush pins. Intercondylar fractures can be pulled together with a screw or bolt. The Moore or Blount plate may be difficult to insert because of comminution, for it may drive the fragments apart. The screw plate is usually applied to the lateral surface of the femur, and the insertion of the screws will tend to draw the fragments together. In the presence of osteoporotic bone, it may be desirable to transfix one of the fenestrations by means of a threaded bolt with washers.

Talotibial Spurs: An Occupational Hazard in Athletes. Dr. Don H. O'Donoghue [13] reported that in an analysis of 240 ankles, 120 in athletes and 120 in non-athletes, it had been found that there is substantially more talotibial spurring in the former than in the latter. He believes that these spurs form as a secondary consequence of forceful hyperdorsiflexion of the foot. In the patients in his series with symptoms, there was usually a loss of the ability to run forcefully, so that a football player was often unable to do his best. Thirteen of the patients with symptoms were submitted to operation. This operation consisted in removal of the spur from both the distal end of the tibia and the neck of the talus, either by a lateral or medial approach. Post-operatively plaster splints were used for ten days, following which a walking plaster boot was used for another ten days. In the operative cases followed to date, there have been no recurrences of spurs and no recurrences of symptoms. Conservative measures have been used in the milder cases.

In discussing the paper, Dr. Frederick Webster [14] reported that he has found spurs in 50 per cent of all athletes examined. He felt the clinical findings were out of proportion to the findings revealed by roentgenograms.

Automotive Crash Injury Research. Mr. John O. Moore [15] described the development of the Automotive Crash Injury Research program as an outgrowth of the studies of aviation crash injuries made during the last World War. Since 1952, the work has been supported by grants from the Defense Department, U. S. Public Health Service, and more recently it has also been supported by grants from the Ford and Chrysler motor companies. A statistical sampling approach of proved reliability has been employed, and a total of slightly more than 2,000 case histories have been collected from the states cooperating in the program (North

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[13] 1111 North Lee Street, Oklahoma City, Oklahoma.
[14] 1000 South 13th Street, Lincoln, Nebraska.
[15] 1300 York Avenue, New York, N. Y.

Carolina, Virginia, Indiana, Connecticut, Arizona, Texas, Minnesota, Maryland, California, and Vermont). Roughly 4,600 individual car occupants were concerned in these cases. Each case history was carefully analyzed and coded, and the information obtained was put on IBM punch cards for processing.

Mr. Moore summarized the findings briefly. Opening of one or more car doors is the most important single factor influencing the pattern of the injury. This occurred in 51 per cent of the injury-producing accidents that were studied and in 75 per cent of all accidents in which a car turned over. Of the occupants who remained in the car only 24 per cent had moderately severe to fatal injuries, whereas 54 per cent of those ejected had this grade of injury. Seventy-five per cent of the occupants involved in the automobile crashes that were studied received injuries. The sites of injury were, in order of frequency, the head, lower extremity, thorax and thoracic spine, upper extremity, abdomen, pelvis and lumbar spine, neck and cervical spine. Seven per cent of the persons injured were killed. Of the head injuries, 87 per cent involved only soft-tissue lacerations and 5 per cent caused fatality. Facial and skull fractures accompanied lacerations of the head only infrequently. In the lower extremity the bones fractured or dislocated were, in order of frequency, the femur, the tibia and fibula, and the bones in the ankle, foot, and knee. Thirty-six per cent of the injuries to the lower extremity involved the femur, being either dislocation of the hip or fracture. In the upper extremity the humerus, radius, and ulna were fractured with almost equal frequency, although none of them were commonly injured. In the chest, if injuries to the thoracic spine are excluded, rib fractures predominated; these fractures were frequently associated with injuries to respiratory organs. In the pelvic region simple fracture of the pelvis was by far the most common injury. Spinal injuries occurred in but 4 per cent of the injured occupants, the cervical region being the portion of the spine most frequently involved. Abdominal injuries were not considered in this discussion.

Mr. Moore outlined briefly future plans to test the effectiveness of safety belts and of design changes in new car models. He made a plea to the attending doctors to fill out the forms should the study reach their areas.

Dr. Murray E. Gibbens [16] discussed this paper, showing slides to illustrate the good and bad features of modern automobiles. He stressed the importance of educating the public to demand safer automobiles, to avoid accidents, and to use seat belts and crash pads in their cars. He favored some form of speed control or governor for automobiles, especially those driven by young people.

Dr. William H. Bickel [17] described the activities of the committee of The American Academy of Orthopaedic Surgeons which was appointed the previous year to explore ways and means of helping in the problem of automotive crash injuries. He pointed out lines along which The Academy's efforts should be directed, including promoting safety devices, discouraging the physically unfit from driving, and educating both doctors and laity.

January 31, 1956

KAPPA DELTA AWARD FOR RESEARCH IN ORTHOPAEDIC SURGERY

Skeletal Lesions Produced by Aminonitriles. Dr. I. V. Ponseti [18] reported that minimal amounts of aminonitriles fed to rats produce degenerative lesions in the epiphyseal plates and at the site of the tendon and ligament insertions. Because of these lesions, a number of skeletal conditions develop, such as curvature of the spine and slipping of the epiphysis. Osteo-arthritis occurs in many joints, and periosteal new bone forms along some of the long bones. In young rats dissecting aneurysms of the aorta may develop. It is surmised that the aminonitriles interfere with the formation of the ground substance.

Punch biopsies in human patients with slipping of the upper femoral epiphysis and with Legg-Perthes disease have demonstrated a lesion in the epiphyseal plate similar to the lesion produced by aminonitriles in experimental animals. It has also been found that the osteo-arthritis and the dissecting aneurysm of the aorta which are found in human patients are histologically similar to the lesions produced in rats by aminonitriles.

Surgery in Spinal Tuberculosis. Prof. Philipp J. Erlacher [19] briefly reviewed the etiology of tuberculosis of the spine. He stated that it is necessary to remove the local lesion in patients with this disease, and he reported that since World War II he had operated upon a series of patients by this method.

He noted that extrafocal fixation of the spine by fusion, a procedure advocated by many, does not attack the lesion *per se*. He believes that the tuberculous tissue must be removed and that the resultant cavity must be sterilized. Furthermore, he advocated packing of the cavity, following excision of the necrotic material, with bone chips or with a block of bone. He mentioned a publication by Ito of Japan, in a 1934 issue of *The Journal*, in which a similar method was advocated.

Prof. Erlacher described the indications and contra-indications for this radical surgery. He advised that the lower lumbar region be approached through a retroperitoneal lumbar incision and that the dorsal region

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[17] The Mayo Clinic, Rochester, Minnesota.
[18] University of Iowa Hospitals, Iowa City, Iowa.
[19] Vienna VI, Lehargasse II, Austria.

Dr. Ignacio V. Ponseti was presented with the Kappa Delta Award by Mrs. H. E. Mueller, Evanston, Illinois, representative of the Kappa Delta Sorority. Looking on are Dr. Paul Lipscomb, Chairman of the Committee on Scientific Investigation, and Dr. Walter P. Blount, President, The American Academy of Orthopaedic Surgeons.

be approached through a costotransverse incision. He had performed no operations in the cervical region. He suggested that sterilization of the cavity be done by means of chlorine and alcohol, followed by instillation of tuberculostatic material or anti-tuberculosis chemicals. For the larger bony cavities, he advised insertion of bone chips or blocks of bone mixed with tuberculostatic powder. In certain cases he had used irrigation tubes and had flooded the area postoperatively with tuberculostatic agents.

He reported that he had operated upon eighty-two patients and showed roentgenograms made from six months to three years after the operations.

The author had not been uniform in his use of bone chips or bone blocks and in his performance of instillation or irrigation. His method had varied from case to case. In fourteen patients the pleura had been opened, although in only one patient had a severe complication resulted. Of the eighty-two patients operated upon to date, only four have died. Only one of these deaths appeared to be a result of the operation.

Long-Term Results in the Bucket-Handle Acetabuloplasty. Dr. I. William Nachlas [20] reported the long-term results obtained in seven patients in whom bucket-handle acetabuloplasty had been done as long ago as twenty-one years. He had designed the operation used in these patients in an attempt to improve upon the usual methods of performing a shelf operation in unstable hips. His operation, he felt, would produce a more satisfactory cup for a spherical femoral head, the depth of the socket being sufficient to house the head securely. The findings of his follow-up study were quite striking in that all the patients showed good stability in the hip with nearly normal hip motion and negative Trendelenburg tests. All showed some degree of limb shortening, a mild limp when tired, but no pain other than the discomfort of fatigue, except in one case in which the difficulty was complicated by polyarthritis. In most cases the roentgenograms showed that there was some abnormality of shape or congruity of the hip joint but that the acetabula were fairly well formed and covered the head by up to two-thirds of the normal amount. Dr. Nachlas concluded that this operation may be useful in the treatment of hips in which the acetabulum is inadequate, for in these hips its use has resulted in well functioning joints without appreciable loss of motion or significant pain after a long term of normal use.

In his discussion, Dr. Allan F. Voshell [21] remarked that Dr. Nachlas was a very patient man to wait

[20] 819 Park Avenue, Baltimore, Maryland.
[21] 101 West Read Street, Baltimore, Maryland.

for such long-term results. He felt that any attempt to reconstruct an acetabulum in which a deficiency has existed is a serious undertaking. Dr. Voshell himself had not done any operations of this type and, therefore, had no analysis of cases. He felt that there could be no doubt that the patients described were considerably better than they would have been had they gone untreated. He went on to question, however, whether the roentgenograms that had been made in these cases actually demonstrated the formation of a new shelf, and he also wondered if this curved shelf had actually remained in the position originally intended.

The paper was next discussed by DR. ALVIN INGRAM [22]. Dr. Ingram felt that any operative procedure aimed at relieving acetabular insufficiency should give, in the long term, a hip that is painless with a good range of motion and without limp. He felt that the results of shelf procedures in general were poor, due to the eccentric position of the head rather than to the shape and size of the head and, furthermore, that the incongruity of the surfaces within such a joint would eventually produce pain. He admitted, however, that the follow-ups reported by Dr. Nachlas did not bear this out and stated that perhaps basic thinking would need revision if the results of bucket-handle acetabuloplasty should continue to be so satisfactory.

In his closing discussion Dr. Nachlas stated that he had not found this operation difficult to perform. The bucket-handle shelf had on certain occasions broken loose from one or the other of its attachments, but this had been overcome by suture or even, in one case, by screw fixation; thus, in the end, there had been no migration of the newly formed shelf. He concluded with the remark that he intended to make another follow-up study of the same cases after another twenty-year period.

The Walter Reed Report on Cineplasty. COL. ERNEST A. BRAY [23], COL. AUGUST W. SPITTLER [24], and LT. COL. MAURICE J. FLETCHER [25] presented an excellent statistical review of 107 cineplasty amputees, operated upon between 1948 and 1953, who had been followed one year or more since the final definitive surgery. Since the ultimate proof of the success of cineplasty is the comfortable and successful use of the prosthesis, it is interesting to note that the authors found that 62 per cent of the patients had continued to wear their limbs after one year. When the patients with biceps cineplasty were classified according to the various amputation levels, it was found that use of the limbs had been continued by 82 per cent of the patients with short below-the-elbow amputation stumps, by 74 per cent of the patients with medium below-the-elbow stumps, by 73 per cent of the patients with long below-the-elbow stumps, and by 66 per cent of the patients with long above-the-elbow stumps. The pectoral cineplasties appeared to have been much less successful, 47 per cent of the patients with long above-the-elbow stumps and only 14 per cent of those with short above-the-elbow stumps continuing to wear their artificial members. It is interesting to note that only 29 per cent of those patients who had discarded the cineplastic prosthesis were currently wearing a conventional appliance. The reasons for individuals not continuing with the use of the cineplastic prosthesis were analyzed and a comparison study was made between this group and patients with conventional limbs. This latter study revealed that 83 per cent of patients with conventional amputations had continued to wear the prostheses as compared with the 62 per cent in the cineplastic group.

On the basis of their careful study of these cases, the authors proposed the following basic requirements for the performance of any type of cineplasty: (1) proper available facilities for surgery, training, and prosthetic maintenance; (2) satisfactory surgical condition of the skin, muscles, and joints; (3) proper motivation of patients (intelligence, intent, interest, cooperation, and vocational maturity); (4) persistent desire for cineplasty after a six-weeks' trial of a conventional prosthesis; (5) necessity to use the prosthesis to perform skilled work; and (6) lack of necessity to use the prosthesis to perform heavy labor.

The authors feel that any below-the-elbow amputee who meets these requirements will be an excellent candidate for biceps cineplasty. In contrast, the above-the-elbow amputee must have a long stump and must be an exceptional adult who has special reasons for needing an increased sphere of action and an improved sense of pressure and position of the terminal device. The pectoral cineplasty is indicated only for the occasional adult who urgently requires an additional source of control for the successful operation of a prosthesis.

Recurrent Ulnar-Nerve Dislocation at the Elbow. DR. HAROLD M. CHILDRESS [26] reported on his experience with dislocation of the ulnar nerve at the elbow. He described two types of such dislocations: type A, in which the nerve rides onto the medial epicondyle; and type B, in which the nerve passes over and lies anterior to the epicondyle. Type A is "incomplete", but because the nerve lies directly over the bone, it is exposed to trauma and is, therefore, often productive of symptoms. Type B is "complete", but the nerve is so located that it is less subject to trauma and thus symptoms are less apt to occur.

Dr. Childress described in some detail his experiences with thirty-four patients and presented the results of a survey of 1,000 selected individuals. In his survey he had found that the incidence of recurrent ulnar-nerve dislocation was 16 per cent, three-quarters of the dislocations being type A and one-quarter being type

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[23] Walter Reed Army Hospital, Washington, D. C.
[24] Tokyo Army Hospital, 8059th AU (Main), APO 500, c/o P.M., San Francisco, California.
[25] Army Prosthetics Research Laboratory, Walter Reed Army Medical Center, Washington, D. C.
[26] 518 Pine Street, Jamestown, New York.

B. All but fourteen of the 162 patients encountered in the survey had bilateral dislocations. The lesion had occurred more commonly in females than in males.

Caution in the strapping of the surgical patient onto the operating table and in the use of abduction splints and casts was advised. In many of the cases all the symptoms had appeared in the hand and none had appeared in the elbow. Direct trauma had often alerted the patient to the dislocation of his nerve, but doubt was expressed that direct trauma could be the cause of recurring ulnar-nerve dislocation.

Treatment was recommended for those patients with symptoms of friction neuritis. A plea for the use of the deep, intramuscular method of transplantation rather than of the subcutaneous method was made.

In his discussion, DR. JAMES E. BATEMAN [27] agreed that the condition is more common than has been generally thought and also agreed that intramuscular transplantation is the treatment of choice.

DR. BENJAMIN E. OBLETE [28] suggested that a shallow ulnar groove was responsible, at least in some cases, for the ulnar-nerve dislocation.

DR. CHILDRESS did not agree, however, stating in his closing remarks that he had found no such anatomical changes in the subjects he had examined.

Soft-Tissue Neoplasms Associated with Congenital Neurofibromatosis. DR. H. RELTON MCCARROLL [29] presented follow-up information concerning forty-six patients whose cases had been previously reported and added ninety cases of this condition to the literature. In his original report he had listed the clinical manifestations of neurofibromatosis under five major headings: cutaneous, subcutaneous, skeletal, vascular, and lymphatic. At this time he added a sixth classification, that of primary neurogenic involvement. His experience indicates that when the lesion is fairly well localized, control can be obtained by local excision of the involved tissue. When the condition is more extensive, however, local measures have not been so successful. Involvement of a single extremity by a neoplasm which cannot be controlled by local excision should be considered an indication for amputation, as should the presence of malignant changes. In the author's series of 136 patients, only three malignant tumors had been found. The clinical manifestations of this condition were described under the six classifications and a method of treatment was prescribed. [The article is printed in full, beginning on page 717, in this issue of *The Journal*.]

Five-Year Follow-Up of Ankle Joint Fusions. DR. J. A. LEO WALKER [30] had previously described a technique for obtaining ankle fusion by means of using the lower three inches of the lateral malleolus as a bone graft. The operation was performed, five or more years ago, on forty-two patients. The average time in plaster required to obtain fusion in these forty-two patients was 175 days or nearly six months; the total period of treatment was just short of one year. Dr. Walker also discussed time loss from work because of the disability. The cause of the time loss was studied in relation to whether pain occurred at the site of operation or at the joint of strain (the mid-tarsal joint).

February 1, 1956

The Management of Congenital Dislocation and Congenital Dysplasia of the Hip Using a Special Splint. DR. FREDERIC W. ILFELD [31] described a splint which has been found useful in the treatment of congenital dislocation and congenital dysplasia of the hip. This splint consists of two metallic thigh cuffs covered with removable washable material and connected to an adjustable crossbar by means of a universal joint. In addition, the thigh bands are connected by a right-angle joint, with stops; this allows up to 90 degrees of motion, enabling the patient to sit and lie. By means of this splint the hips can be maintained in a position of abduction while at the same time active motion of the hips, knees, and ankles is permitted. The author also described an adjustable "out-rigger" bar which may be attached to the cross piece and anchored to the lower portion of one leg; by means of this bar internal rotation of the hip can be maintained.

The author recommended the use of this splint as the primary procedure in the treatment of younger patients with congenital dysplasia or congenital dislocation of the hip. He also recommended its use as a means of splinting following reduction of a dislocated hip by other means in children of an older age. He advised that the splint be worn constantly for several months, being removed only during bathing and during changing of the covers of the metallic thigh cuffs. At the time the splint is removed for bathing, rotation and abduction exercises should be carried out in the hips.

Dr. Ilfeld described the use of this splint in twenty-two cases of congenital dysplasia of the hip and stated that uniformly excellent results had been obtained by using the splint only at night for an average of six months.

He also reported the use of the splint as the primary method of therapy in forty-one patients with disloca-

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[29] 3720 Washington Boulevard, St. Louis, Missouri.
[30] 1538 Sherbrooke Street West, Montreal, Quebec, Canada.
[31] 436 North Roxbury Drive, Beverly Hills, California.

tion or subluxation of the hip. The youngest patient in whom this treatment had been instituted was one and one-half months and the oldest was thirty months; the average age was seven months. The splint had been worn constantly for an average of five months and had then been used as a night splint for an additional four months. He stated that the results in this group, after an average follow-up of twelve months, could be classified as *good* in 94 per cent of the cases; some residual limitation of motion was present in the remaining 6 per cent. The preliminary results in this group, as shown by roentgenograms, had been classified as *good* in 77 per cent of the cases; aseptic necrosis of the capital epiphysis had been present in 12 per cent and some moderate deformity in 9 per cent. He stated that redislocation of the hip had occurred in one case. This patient had been later treated by closed reduction and plaster fixation, with a satisfactory result. In two additional cases the splint had failed to bring about a reduction of the dislocation. In both of these patients good results had been obtained following treatment by closed reduction, plaster fixation, and, later, abduction splinting.

The splint was used successfully in thirty-one patients following reduction and the application of casts in order to shorten the time in plaster or to facilitate the growth of the hip. The splint replaced the cast as early as four weeks after reduction.

Illustrations were shown to demonstrate the excellent results obtained.

Vertebral Lipping in the Lumbar Spine. Dr. Ian Macnab [32], Dr. R. I. Harris [33], and Dr. Carroll Laurin [34] reported their investigation on the relationship of vertebral lipping to low-back pain. Seventy-four fresh spines removed at autopsy and fifty macerative spines of known age were studied by anatomical, biomechanical, and pathological techniques. Five types of spurs or "spondylophytes" were identified and their significance discussed.

1. The "traction spur" arises from the vertical surface of the vertebral body, three to four millimeters from the intervertebral border, and terminates at the level of the vertebral border, never extending out over the disc. It is always associated with an unstable segment or with changes in the disc known to be consistent with instability. Abnormal mobility without collapse of the disc is believed to cause increased traction on the outermost annulus fibers, thus stimulating the formation of traction spurs at the point of attachment of the fibers.

2. The "claw" spondylophyte is the most common spur and is usually found on the adjacent vertebral margins in the lower lumbar spine, in the cervical spine, or on the concave side of a lateral curvature. It is large and thick at the base, tapering to a point as it arches outward over the disc, where it may meet and interlock with or, rarely, fuse with the opposing spur arising from the adjacent vertebra. It is usually associated with a degenerated disc which has collapsed, that is, lost height and bulged around its circumference. Its formation is thought to be the result of the horizontal pull on the annulus fibers which occurs when a degenerated disc collapses.

3. The "cap" spondylophyte is found in the lumbar region on the anterolateral aspect of the annulus, usually in association with claw spondylophytes. It never has bony continuity with the adjacent vertebral bodies and may, therefore, resemble a fracture of a claw spondylophyte. It develops as a result of metaplasia of the annulus with resultant new-bone formation.

4. "Confluent" spondylophytes occur only in the thoracic region, either anteriorly or on the concave side of a scoliotic curve. They produce bony fusion between vertebrae. This fusion may extend over four or more adjacent segments. Confluent spurs are always associated with degenerated discs which have undergone fibrocartilaginous metaplasia and hence neither bulge nor permit any movement.

5. The "bubble" spondylophyte appears on the roentgenograms as multiple shadows in the annulus, anterior in the thoracic region and posterior in the lumbar spine. They differ from "cap" spondylophytes in that they always lie within the vertebral borders or within the substance of the disc. They occur in discs in which extensive degenerative changes have developed and there is invasion of the annulus by granulation tissue. Frequently they are associated with instability and abnormal movement. They represent calcification and ossification at the site of healing tears in the annulus.

The authors emphasized the following: Spondylophytes are always associated with a degenerated disc, and they form and progress only in the presence of movement at the interspace where they are located. Spur formation or lipping is therefore a self limited condition since movement at the involved interspace eventually ceases due either to collapse of the disc space or to increasing spur formation which precludes further movement. Spondylophyte formation appears to be the result of anatomical and mechanical factors, for spurs occur characteristically on certain parts of the interspace, and the type of spur varies in different regions of the spine. In the lumbar region they are found most commonly on the lateral aspect of the intervertebral space, less often on the anterior aspect, and rarely posteriorly. In scoliosis the type of spur that occurs on the concave surface is different from that which occurs on the convex surface. Spurs rarely cause nerve-root pressure in the lumbar region. No constant relationship can be found between the formation of spondylophytes and

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[33] 170 St. George Street, Toronto, Ontario, Canada.
[34] The Hospital for Sick Children, University Avenue, Toronto, Ontario, Canada.

the presence of posterior-joint arthritis. In the natural course of disc degeneration, instability of the segment is of relatively short duration, occurring while the disc space is collapsing or before large spurs have had a chance to develop. In clinical practice instability is seen most commonly in association with traction or bubble spurs which are small and which involve an isolated segment; it is usually present at a time when the normal disc height is still maintained.

The relationship of spur formation, posterior-joint arthritis, and back pain was considered. Pain was attributed to either instability or posterior-joint arthritis. An attempt was made to relate pain to the condition of the disc, the types of spur formation, and the presence of posterior-joint arthritis.

Dr. William J. Tobin [35] discussed this paper and showed some interesting slides depicting the spines of ancient man and animals.

Dr. Edgar M. Bick [36], in discussing this paper, suggested that calcification within the annulus should not be classed as spondylophyte formation since it probably represents calcification in degenerating tissue and not bony response to strain, as is the case with the other spondylophytes. He also pointed out that the vertebral ring is a traction apophysis and hence should not be called an epiphyseal ring.

Subtalar Bone Block. Dr. G. Wilbur Westin [37] and Dr. Cameron B. Hall [38] described their experience with the use of subtalar extra-articular arthrodesis in a series of sixty-two patients treated over a four-year period. Selected for this study were patients with paralytic valgus deformity, paralytic calcaneovalgus deformity, and paralytic flail feet; a miscellaneous group was also studied. The surgical procedure described is similar to that previously reported by Dr. Grice in 1952 and 1955 issues of *The Journal*.

The authors recommended that muscle imbalance should be corrected by tendon transplantation. In their series they had used stainless-steel sutures with pull-out wires to fix the tendons to bone. Correction of equinus deformity had been accomplished before operation by means of a wedging cast. No heel-cord lengthenings had been performed in this series. Solid union of the grafts was obtained in all instances.

The importance of restoring normal alignment between the calcaneus and the talus was stressed. In three patients a varus deformity of the foot had developed as a result of overcorrection. Failure to adequately correct the equinus deformity and to restore the muscle balance resulted in recurrence of the valgus deformity in three patients in whom the talus had been displaced into a valgus position in the ankle mortise, a procedure which had produced retardation of growth in the lateral aspect of the distal tibial epiphysis.

Excellent results had been obtained in the group of patients with calcaneovalgus deformities. In these patients the subtalar fusion had been combined with transplantation of the posterior tendons to the apophysis of the calcaneus.

When the foot has been properly aligned and muscle imbalance has been corrected, this procedure may be of definitive value. A foot in which a triple arthrodesis may be indicated in later life will show good results, for the height of this foot will have been maintained and there will be less deformity to correct by means of the triple arthrodesis.

A Two-Stage Stabilization Procedure for Correction of Calcaneocavus Foot Deformity. Dr. George E. Scheer [39] and Dr. C. H. Crego, Jr.[40] described and recommended a two-stage operative procedure for the stabilization of the calcaneocavus foot and for the correction of the deformity of this foot. At the initial operative procedure a posterior approach is used; the subtalar joint is excised and a posterior wedge of the calcaneus is removed. In the closure of the defect the relatively vertical position of the calcaneus can be corrected and a more normal horizontal position can be substituted. The authors advised against posterior displacement of the hind part of the foot.

After the foot has been immobilized by plaster in the corrected position for four weeks, the second stage of the operation is carried out through the usual anterolateral approach. At this time the calcaneocuboid and talonavicular joints are excised and the wedges necessary for correction of the deformity of the fore part of the foot are made. The authors advised that section of the plantar fascia be done as a part of this second-stage procedure. They also stated that posterior-tendon transfers could be carried out at the time of the first-stage procedure, although they advised against concomitant transplantation of the anterior tibial tendon through the interosseous space. They stated that any anterior-tendon transplants which may be indicated could be carried out as a part of the second stage of the operation.

Dr. Scheer and Dr. Crego feel that this two-stage operative procedure is very useful in the treatment of a severe calcaneocavus deformity. They reported that satisfactory results had been obtained in twenty-one of the twenty-four cases available for evaluation.

In his discussion Dr. C. E. Irwin [41] stated that, in his experience, a one-stage surgical procedure has

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[36] 30 East 60th Street, New York, N. Y.
[37] 1930 Wilshire Boulevard, Los Angeles, California.
[38] 153 South Lasky Drive, Beverly Hills, California.
[39] 1033 Missouri Theater Building, St. Louis, Missouri.
[40] 634 North Grand Avenue, St. Louis, Missouri.
[41] Professional Building, Atlanta, Georgia.

been proved to be entirely satisfactory for the correction of this deformity; he saw no reason to subject the patient to a two-stage operative procedure.

A Clinical Evaluation of Operative Procedures for Congenital Talipes Equinovarus. Dr. Raymond F. Kuhlmann [42] and Dr. John F. Bell [43] presented a review of fifty-three patients with seventy-eight congenital club feet upon which a total of 154 surgical procedures had been performed. One hundred and thirty-six of the operative procedures had been directed toward correcting soft-tissue contractures and eighteen had been bone procedures. An average follow-up of 7.7 years had been effected through the Vermont Crippled Children's Services.

Tendo-calcaneus lengthening with posterior capsulotomy of the ankle joint had been performed in thirty instances. The average age of the patients was 2.4 years. The results had been *good plus to excellent* in 73 per cent. Some loss in the arc of plantar flexion had been noted. It was concluded that the procedure was an effective method of correcting an equinus deformity of the hind part of the foot.

Tendo-calcaneus lengthening alone had been performed in twelve instances. The average age of the patients was one year. The results had been *good plus to excellent* in 50 per cent. This procedure was not as effective alone as it was when combined with posterior capsulotomy.

Release of the ligamentous structures on the medial aspect of the foot had resulted in a *good plus to excellent* rating in 31 per cent of sixteen procedures. Although the initial correction had been good, the deformity had recurred as a rule within one to two years. This procedure had been used only in cases of exceptionally resistant club-foot deformity. Correction by means of skeletal traction had been done in eight instances, with fair results. Although the early correction had been good, the deformity had usually recurred.

Ligamentous release and skeletal traction combined had been done in six instances. The immediate postoperative results had been good, but the deformity had usually recurred.

Plantar fasciotomy had been used as an adjunctive procedure to correct the cavus element of the deformity in four patients.

Lateral transference of the anterior tibial tendon had been done in twenty-nine instances. The average age of the patients was five years. The procedures had been done as a means of correcting a varus deformity, and *good plus* to *excellent* results had been obtained in 86 per cent. It was considered an effective means of restoring balance in the foot, but the authors warned against the possibility of overcorrection and recommended that the tendon be placed no further laterally than the fourth metatarsal.

In the bone operations excellent results had been obtained by means of tarsal arthrodesis, performed after the bone was mature. Reoperation had frequently been necessary if the procedure had been done before the patient was eight years old.

In their discussion the authors emphasized that in cases of club-foot in which the initial treatment is conservative, there often comes a time when the most effective approach is to resort to surgical measures such as heel-cord lengthening, capsulotomy, or tendon transfer.

Dental-Arch Abnormalities in Idiopathic Scoliosis and Their Significance. Preliminary Report. Dr. Charles V. Heck [44] and Dr. Everett A. Grimmer [45] presented a study of the dental structures of 140 patients with scoliosis. This study indicated that patients with idiopathic scoliosis have a higher incidence of deformities of the dental arches than do either "normal" people or patients with paralytic and congenital scoliosis. The materials used in this study included photographs, roentgenograms, and dental molds made of plaster-of-Paris. The significant changes noticed were overbite, a high angular palate, irregular contour of the dental arches, and recession of the mandible. Overbite was the most consistent abnormality found in this survey. Overbite may be due to a discrepancy in the closure of the growth zones of the maxilla or to a short mandible. High angular palate was a common finding in children with idiopathic scoliosis.

A group of children with functional deformities of the spine due to a short lower extremity or to an unstable hip did not show any deviations in dental structure from the normal population. Of forty-six patients having idiopathic scoliosis, thirty had one or more of the dental deformities mentioned. By contrast, only three of the seventeen patients with congenital scoliosis had any abnormality of dental structure. Of a large group of children with paralytic scoliosis there were also only three who had any abnormality of dental structure. Three out of four patients with spinal deformities associated with neurofibromatosis had dental abnormalities. These findings suggest that the influence of common factors on growth and development may be reflected in both the dental and spinal structures.

Experiments in Epiphyseal Growth and Repair. Dr. Robert S. Siffert [46] described experiments which were carried out on young rabbits, six weeks of age, in order that the effect of stapling and epiphysiode-

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sis might be studied. The effect of injuries to the epiphyseal plate caused by wires, lacerations, curetting, drilling, and stapling was also studied.

In the stapling experiments small stainless-steel staples were inserted across the lower femoral epiphysis. The animals were sacrificed within three to six weeks after operation. Following stapling of the medial side of the femur, bowing of the limb developed routinely. The histological sections revealed that on the unstapled side the metaphyseal trabeculae were normal but that on the stapled side the trabeculae were sparse and there was subepiphyseal condensation of bone. The existing cartilage cells continued to mature, but there was failure of the epiphyseal cartilage cells to proliferate. As the cartilage cells matured, the vascular invasion from the metaphysis continued and new bone was deposited. There was thinning of the epiphyseal plate until finally epiphysiodesis occurred. The author concluded that at this point the process was not reversible, and he warned that possibly the staples should not be left in too long if it is anticipated that growth will resume after their removal. He suggested that the presence of excessive thinning of the epiphyseal line and of a subepiphyseal line of bone condensation on the roentgenogram might be a warning that epiphysiodesis may ensue.

In another group of rabbits Kirschner wires were inserted across the epiphyseal plate by the intramedullary route. Histological and roentgenographic studies showed that growth continued until the epiphyseal plate grew beyond the end of the wire. The epiphyseal defect was healed by means of bone formation, which resulted in the development of a transepiphyseal bone peg. The author reported that in one instance the upper femoral epiphysis, which was transfixed with a nail because of slipping of the capital epiphysis, grew beyond the end of the nail but did not slip any further. He postulated that the transepiphyseal bone peg might have produced stability and prevented further slipping.

Curettage and drilling of the central portion of the epiphyseal line resulted in the development of epiphysiodesis in the central portion but did not produce deformity; occasionally it caused inhibition of growth. Eccentrically placed drill holes or curettage resulted in irregular growth and deformity.

Experiments in which the iliac apophysis was displaced demonstrated that the separation occurred through the metaphysis and that the epiphysis retained the potential of longitudinal growth. As a result of these experiments, it was decided to make transverse cuts at various levels across the epiphyseal plate. The transverse cuts made through the metaphyseal area caused no interference with growth, but when the cuts were made at the level of the resting or proliferating cartilage cells, healing occurred by scar formation and no new growth occurred.

Although the experiments were performed on rabbit epiphyses, the similarity between the results of these experiments and the findings of clinical experiences would suggest that the experiments may be of value in explaining and perhaps preventing epiphyseal deformities.

A Critical Evaluation of a Method of Epiphyseal Stimulation. Dr. Earnest B. Carpenter [47] and Dr. James B. Dalton [48] reported that an attempt to stimulate growth by increasing the vascularity of the epiphysis had been performed upon thirty patients. These patients had been followed for at least thirty months after operation. A block of bone one and a half inches long had been removed from the anterior surface of the femur just proximal to the floor of the femoral condyle and just distal to the proximal tibial epiphysis. The medullary centers had then been thoroughly curetted and removed. The cavity created had been tightly packed with chips of ivory. A cylinder cast had been applied and weight-bearing permitted as soon as it could be tolerated. Two patients had sustained fractures four weeks and six months after operation as a result of trauma. There had been no other complications.

Measurements had been made by means of standardized roentgenographic control, and the skeletal age had been determined by means of roentgenograms of the wrist. Only five patients had obtained a half inch or more of stimulated growth. Ten patients had gained an eighth of an inch and eleven had gained a quarter of an inch. Very little increased growth had occurred after six months.

The authors concluded that the operation might inhibit increasing discrepancy in the young child with complete flaccid paralysis caused by poliomyelitis. In most instances the amount of increased growth obtained was not sufficient to justify the operative procedure.

February 2, 1956

Ten-Year Survival in a Case of Osteogenic Sarcoma of the Tibia with Pulmonary Metastasis. Dr. Raphael R. Goldenberg [49] presented the case of a seventeen-year-old girl upon whom a mid-thigh amputation had been carried out because of osteogenic sarcoma of the tibia. During the eight months prior to amputation the patient had complained of pain at the level of the middle and distal thirds of the left tibia. She had at first refused amputation, but three months after the biopsy the pain had become so severe that she had agreed to the operation. She had remained well and free from symptoms until approximately three

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years after the operation, at which time a roentgenogram had revealed a tumor shadow in the right upper chest. A lobectomy had been performed by Dr. R. H. Overholt. The patient has made an uneventful recovery and has remained well, without any evidence of recurrence, since that time. The tumor in the lung was described as microscopically identical with that of the tibia. The author stated that he believes this to be the first instance of survival of a patient ten years following a diagnosis of osteogenic sarcoma of the tibia and seven years after lobectomy for a pulmonary metastasis.

Metastases to Other Bones from Osteogenic Sarcoma. Dr. Roy I. Peck [50] reported eight cases of osteogenic sarcoma associated with similar lesions in other bones. Seven of the tumors were originally diagnosed as osteogenic sarcoma and the eighth was originally diagnosed as chondrosarcoma. The youngest patient was a twelve-year-old girl, and the oldest was a sixty-three-year-old woman. The cases were divided equally between males and females. While it is possible that the tumors were of multicentric origin, it is also perfectly possible that metastases had occurred by means of the vertebral venous plexus.

Chondrosarcoma. A Surgical and Pathological Problem. Review of 212 Cases. Dr. D. C. Dahlin [51] and Dr. E. D. Henderson [52] stressed the necessity for early accurate diagnosis of this neoplasm and for early radical surgical treatment. The lesion is rarely found in individuals who are under twenty years of age and is found most commonly in individuals who are between the ages of thirty and seventy. In approximately one-half of the 212 cases reported by the authors, the primary malignancy had arisen from either the pelvis or the thoracic cage. The usual clinical picture was a slow-growing tumor with local pain. The changes shown by the roentgenograms were quite characteristic, including fusiform swelling associated with cortical destruction and fuzzy or mottled calcification within the tumor. The lesions may be divided into central or peripheral types and into secondary or primary types, in accordance with their origin and location.

In this series, nineteen of the 212 chondrosarcomata apparently had arisen from osteochondromata, twelve of these nineteen occurring in patients with multiple osteochondromata. There was no case in which it could be proved that the malignancy had arisen from an enchondroma.

The authors discussed the varied histological pictures routinely presented by these tumors. They reported that the microscopic picture varies markedly from one region of a large tumor to another, and they pointed out that recurrent tumors may be more malignant and may show more cellular activity than primary unmolested tumors.

The authors feel that curettage of a tumor is inadequate treatment, as there is often local extension away from the central lesion. A ten-year symptom-free period of survival is required before the patient is considered cured.

Of 109 patients treated by simple curettage, x-ray therapy, or other inadequate means, only four (4 per cent) were alive and symptom-free after ten years. Of thirty-four patients who were considered to have adequate surgical treatment, fourteen were alive and well after ten years, a very satisfactory proportion (41 per cent).

The realization that the surgeon has but one good chance to cure chondrosarcoma of the pelvic bone, thoracic cage, shoulder girdle, humerus, and upper end of the femur should govern the management of tumors in these locations. It is most important that an inadequate surgical and conservative operation should not be attempted. Accurate diagnosis and clinical evaluation are essential.

The Psychiatric Aspects of Low-Back Pain. Dr. Lee T. Ford [53] and Dr. Robert L. Lam [54] called attention to the well known, but often forgotten, fact that there is considerable overlapping in a patient's functional and organic complaints. This is particularly true in patients with low-back pain. It is an extremely difficult problem, at times, to differentiate between these two factors and to evaluate adequately which component should take precedence in the treatment.

It was clearly pointed out that a complete history should be obtained and that thorough physical, neurological, and psychological examinations should be made. The authors stressed the need for the close cooperation of the orthopaedic surgeon and the psychiatrist in determining which phase of the patient's complaints should be treated first, if the complaints should be treated at all. They presented two case reports and described a method of study, based on repeated orthopaedic and psychological examinations, by means of which a proper diagnosis may be determined. It is interesting to note that the authors used sodium amytal in their interviews with some of these patients in order to obtain a more accurate history; they also carried out physical examinations while the patients were under the influence of the sodium amytal.

The cases of 114 patients were reviewed for this study. One hundred and eight of these cases were studied by an orthopaedic surgeon and a neuropsychiatrist, while six others were studied by a neuropsychiatrist and a

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neurosurgeon. Twenty-five of the 114 patients were given sodium amytal during the interviews; the complaints of twenty of these patients were judged to be predominantly functional. Even without the use of sodium amytal during the interviews, it was felt that the majority of the difficulties of sixty-two of the patients (54 per cent) were functional. The difficulties of thirty-one patients (28 per cent) were considered to be equally organic and functional, while the complaints of twenty-one (19 per cent) were diagnosed as predominantly organic. The fact that there seems to be a much higher percentage of functional disabilities in patients who are involved in litigation (common law or workmen's compensation) than in other patients was stressed.

The case reports demonstrated that the functional component can be brought out by the use of sodium amytal during interviews.

It was again stressed that the orthopaedic surgeon must be aware of the functional components and that he must either be able to penetrate the patient's wall of resistance himself or, even better, have a close liaison with a neuropsychiatrist who is willing to take on the burden of handling the functional disability, both by aiding in the diagnosis and, if necessary, by giving the patient psychiatric treatment.

Radiation Sterilization of Bone Transplants Using Radioactive Cobalt. Dr. Paul H. DeVries [55], Dr. Carl E. Badgley [56], and Dr. J. Ted Hartman [57] presented a very brief report of their attempts to sterilize bone by various methods and described the shortcomings of each of the methods used. During the removal of bone at autopsy, even if meticulous techniques are used, 20 per cent of the bone is contaminated and is, therefore, not useable unless further sterilized. The authors described a method of sterilization in which radioactive cobalt (Co^{60}) is used.

Bone is removed at autopsy, without any sterile precautions. (The ilium is the most favored site.) The bone is then cut into thin wafers on a heavy band saw, is placed in glass tubes, and is freeze-dried. The glass tubes are sealed and exposed to radiation from Co^{60} for a period of twenty hours. An electron accelerator has a low-penetration power and thus, if this apparatus were used, only the surface of the bone would be sterilized. Radioactive cobalt has a high-penetration power, however, and for this reason it was chosen. After the glass tubes have been withdrawn from the radiation "furnace", they are stored at room temperature until needed. When a transplant is to be used, the outside of the glass may be sterilized by the same technique used to sterilize a tube of catgut. The glass is then broken and the bone withdrawn.

The radiation level used is of interest. It is known that two million roentgen equivalent physicals will kill most bacteria and that three million will kill large viruses. In order to secure absolute sterility, the authors exposed the bone to four million roentgen equivalent physicals, the amount necessary to kill all small viruses. The authors stated that no wound infections occurred following use of this bone but that in a few cases there was some mild serous drainage. They reported using the prepared bone in seventy cases and showed roentgenograms of several of their patients.

In his discussion Lt. Cdr. George W. Hyatt [58] reviewed the presentation in light of his experiences at the Tissue Bank, National Naval Medical Center, Bethesda, Maryland. He strongly recommended that the details of the freeze-dry method be precisely described. His group has had no experience with Co^{60} as an irradiation source for bone sterilization. They have had experience with cathode-ray sterilized bone grafts, however, and he reported that excellent short-term results have been obtained with the use of human frozen homogenous bone sterilized by this method. He thought that the use of four million roentgen equivalent physicals might lead to graft damage. He emphasized the difficulty of evaluating graft-to-host union.

The Dowel Intervertebral-Body Fusion as Used in Lumbar-Disc Surgery. Dr. B. R. Wiltberger [59] reported his experiences during the past four years with the dowel intervertebral-body fusion. There are some very definite advantages and also some disadvantages to this procedure, which has been slowly accepted by orthopaedic surgeons.

The advantages are: (1) the use of an intervertebral graft is physiologically sound, for the graft is placed under compression and has perfect contact with the host bone; (2) the procedure is atraumatic; (3) the dowel itself limits bleeding and prevents extrusion of any remaining degenerated disc material; (4) the precision instruments that are used are designed to prevent blind penetration which may lead to injury of large anterior vascular structures; (5) the dowel graft prevents collapse of the intervertebral disc space; (6) precision grafting eliminates any need for removal of too much bone; (7) the posterior elements are undisturbed, so that future access to the spine, if necessary, is available; and (8) the interbody fusion may be used when previous surgery has destroyed the posterior elements.

The disadvantages are the detailed precision that is necessary to perform the procedure properly, the

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greater risk of injury to the dura and nerve roots, the possibility of involvement of the vertebral bodies if infection develops, and the possibility of slipping of the grafts.

Dr. Wiltberger very carefully described the precision instruments that are needed and the care that must be taken in retracting the nerve roots above and below. The necessity of removing the cortical end plates of the vertebral body above and below was emphasized, and the technique of using one dowel or two dowels was described. The use of tibial cortical bone and iliac bone was also described.

Forty-six of the fifty-two patients in this series were available for frequent examination and review; in this group fifty-six interspaces had been operated upon. Each patient had been followed-up for at least two years. The results had included six non-unions, most of which had occurred between the fourth and fifth lumbar vertebrae. Two of these non-unions had been in the group of twenty-six patients treated by bilateral dowel fusions, and four had been in the group treated by single dowel fusions. Three of the non-unions had occurred among the ten patients in whom cortical tibial grafts had been used and three had occurred among the thirty-six patients in whom iliac grafts had been used. It was felt that the tibial graft was superior to the iliac graft despite the fact that proportionately more failures had occurred in the former group, for two of the failures in this former group had been technical failures. There had been two deep wound infections in this series. In two cases the graft had extruded, and in one foot drop had occurred. There had been no deaths. The results of this series were: 70 per cent, very good; 17 per cent, improved; and 13 per cent, not improved.

SCIENTIFIC EXHIBITS

Can Contrast Hip-Joint Arthrography be Useful? Dr. Albert S. Atwood, Dr. David B. Heller, and Dr. Maurice M. Pike of the Newington Home and Hospital for Crippled Children, Newington, Connecticut, demonstrated the uses of contrast hip-joint arthrography in cases of Legg-Calvé-Perthes disease and congenital dislocation of the hip. Although arthrograms showed the shape of the cartilaginous femoral head in patients with Legg-Calvé disease, they did not provide any prognostic information. The procedure was considered to be of no value.

The findings in a series of arthrograms performed on thirty-seven patients with congenital dislocation of the hip were also presented and the following practical considerations were stressed: (1) Contrast hip arthrography can furnish definite information as to the relationship of the cartilaginous femoral head and the acetabulum and is thus useful in diagnosis and treatment of this deformity. (2) Arthrography may help in the differential diagnosis of hip problems in the infant by demonstrating the exact size, shape, and relationship of the bones of the hip-joint. (3) At the present time, the use of contrast arthrography in cases of congenital dislocation of the hip is of no value as a means of determining whether or not open reduction is necessary.

Freeze-Dried Cobalt-Irradiated Bone for Bone Grafts. Dr. Paul H. DeVries, Dr. Carl E. Badgley, Dr. J. Ted Hartman, and Dr. Donald Maxwell of the University of Michigan, Ann Arbor, Michigan, presented their method of preparing, sterilizing, and storing homologous bone grafts by freeze-drying and irradiation with radioactive cobalt.

Data were presented regarding the acceptance by the host (a dog) of untreated bone grafts and of bone grafts prepared by irradiation, by freeze-drying, by freeze-drying and irradiation, by deep freezing, by autoclaving, and by boiling.

This material showed that the host tissue had reacted as favorably to homologous bone prepared by freeze-drying as it had to bone prepared by any other method and that it had reacted more favorably to this bone than it had to boiled or autoclaved bone.

Spondyloschisis and Spondylolisthesis in Children. Dr. Dan R. Baker and Dr. William McHollick of Guthrie Clinic, Sayre, Pennsylvania, presented the results of a study of the incidence of spondylolisthesis in six-year-old children. This study was stimulated by the fact that there is still a considerable difference of opinion among authorities as to the cause of spondylolisthesis.

A mass roentgenographic survey of 400 first-grade school children, six to seven years of age, had been carried out with the cooperation of local schools. Following the completion of this survey, roentgenograms had been made of all the members of the fifteen families of the children found to have either a defect of the pars interarticularis or a definite spondylolisthesis.

The exhibit presented the lateral and oblique roentgenograms which had been made of eighteen children who had been found to have a defect. Also presented were tables summarizing (1) the distribution as to male and female among these children and (2) the incidence of this defect in the fifteen families of whom roentgenograms had been made.

The study of the family incidence of these defects showed the following: In four families the father was found to have either a defect in the pars interarticularis or a definite spondylolisthesis; in two families the mother had a defect; and in one family both the parents had a defect. In these seven families, in which there was a total of sixteen children, eight or 50 per cent of the children had a spondylolisthesis. In the family in which both the mother and father had this defect, the two children were also positive, making the incidence in this family 100 per cent. In the seven families in which the parents were negative there were twenty-two children, of whom seven were positive. In the remaining family the mother was negative. The status of the father, deceased, was unknown. Three of the six children in this family were positive. On the basis of these findings, it would appear that the father was probably also positive.

Of the 400 children examined, 175 were females and 225 were males. Six of the females were found to have either a spondyloschisis or a spondylolisthesis, and twelve of the males showed similar defects. These eighteen children constituted 5 per cent of the total group, a figure which is comparable to that found in surveys of adults. Of the fifteen female parents examined, three were positive, an incidence of 20 per cent; and of the fourteen male parents examined, five were positive, an incidence of 36 per cent. The total parental incidence was 28 per cent. In the families in which at least one parent was found to have this lesion, the incidence among the children ranged from 40 to 100 per cent. In the seven families in which the parents were found to be negative, the average incidence among the children dropped to 32 per cent.

Epidemiology of Multiple Fractures. Col. Joseph W. Batch and Lt. Col. John D. Ashby of the Brooke Army Hospital, Brooke Army Medical Center, San Antonio, Texas, presented an epidemiological study of multiple fractures. The study was limited to cases where two or more bones were fractured, but it did not include cases in which the fractures were of both bones of the forearm or leg or of the bones around the joints. Fractures incurred in battle and fractures resulting from non-battle injuries were studied and compared. There were a total of 344 patients with 1,061 fractures. Causative factors were analyzed with regard to the agent causing the fractures, the environment in which the fractures occurred, and the individual receiving the fracture. The frequency with which fractures in each major bone were associated with additional fractures in other bones were tabulated. There was a high incidence of fractures in the femur, tibia, and humerus.

The number of open and closed fractures as well as the major associated injuries and complications in each group were tabulated. The frequency with which each general method of management had been used and the degree of functional recovery which had been obtained in the two groups were also recorded.

A Diagnostic Reference File for Orthopaedic Surgery Using the McBee Punch Card. Dr. Louis W. Breck, Dr. W. Compere Bascom, Dr. Morton H. Leonard, and Dr. John E. Emmett of El Paso, Texas, presented a simple method of preparing a diagnostic file for use in orthopaedic clinics or private offices. This method was designed to facilitate the statistical analysis of cases and to provide cross references to the patients' charts. (See page 891.)

Arthroplasty of the Knee, Using Cutis Interposing Membrane. Dr. Joseph E. Brown, Dr. Wilbert H. McGaw, and Dr. D. T. Shaw of St. Luke's Hospital, Cleveland, Ohio, presented case studies to illustrate the use of cutis grafts as interposing membranes in knee joints requiring arthroplasty. The cutis graft consists of skin from which the epidermis and the subcutaneous fat has been removed by a technique employing the Padgett Hodd Dermatome. The superficial surface of the graft is placed in contact with the bone, so that the deeper surface forms the synovial lining of the joint and the quadriceps pouch as well as the new articular surface.

A technique for anchoring the graft by means of pull-out wires was demonstrated, and the locations of the grafts in the cases reported were described. Emphasis was placed upon the fact that the graft should cover the femoral epicondyles and should extend proximally beneath the extensor mechanism far enough to restore a gliding surface.

The results in four patients with follow-ups of from two to six years were rated as successful or good. Their knees had a minimum of 60 degrees of motion with no instability or significant pain. There had been no instances of epidermoid-cyst formation, re-ankylosis, or infection.

A biopsy of a joint in which a cutis graft had been inserted three and one-quarter years previously from a non-weight-bearing area revealed that a part of the graft had been converted into a synovial-like membrane. The fate of the cutis graft in the weight-bearing area was not determined.

Xeroroentgenographic Study of Bone. Dr. Crawford J. Campbell, Dr. John Roach, Dr. Andres Grisolia, and Dr. Eichero Asai, of Albany Medical College, Albany, New York, presented a comparative study of xeroroentgenograms, conventional roentgenograms, and pathological sections of bone specimens. Eight cases were presented as illustrations.

Xeroroentgenography is a photoelectric process, the basic element in which is a metallic plate, which is coated with a thin layer of selenium (a semiconductor). A homogenous positive electric charge is applied

to the layer of the selenium, and when the plate is exposed to x-rays, this charge is selectively dissipated. The image is made visible by dusting the surface of the plate with negatively charged powder granules. Because of the simplicity of the equipment required, this process could be used in large-scale catastrophes. The excellent detail afforded by this method in demonstrating normal and abnormal calcification and ossification was illustrated in bone sections one-third of an inch in thickness; the detail obtained by its use was superior to that obtained by conventional roentgenography.

Architectural Stress Pattern of the Femoral Neck, Lower Radius and Lower Tibia in Correlation with the Occurrence of Fractures in These Areas. Dr. Earnest B. Carpenter and Dr. Carl J. Roncaglione of the Medical College of Virginia, Richmond, Virginia, examined the trabecular patterns of the proximal end of the femur and of the distal ends of the radius and tibia in over 200 individuals in order to determine if the structure of these bones is different in the white and colored races. The study was undertaken because a marked difference had been observed between the white and colored races with regard to the incidence of fractures of the hip, of Colles' fractures, and of Pott's and Cotton's fractures. The incidence of all three fractures is greater in the white race than it is in the colored, the ratio being ten to one for hip fractures, six to one for Colles' fractures, and three to one for Pott's and Cotton's fractures. The data used in this study were collected over a period of years on the Orthopaedic Service of the Medical College of Virginia, Hospital Division, Richmond, Virginia. In the area served by this hospital the ratio of white to colored is approximately three to two.

The stress patterns were studied by means of magnification roentgenograms obtained with a fine focal-spot roentgen tube. The age range of the individuals studied was twenty to eighty years. Many individual patterns of bone architecture were found in subjects of all ages in both races, but no consistent patterns which could account for the difference in the incidence of the fractures in the two races were identified.

In the older colored males the patterns of the trabeculae in the lower portion of the femoral neck were larger and more roentgenographically distinct than they were in the young males. This observation correlated with the infrequent clinical occurrence of hip fractures in the older group.

All of the roentgenograms showed that osteoporosis was progressively more frequent in the older subjects; the youngest patients in whom this condition was found were about thirty. In general osteoporosis appeared earlier and was more severe in the white than in the colored patients, a finding which was true for patients in whom the radius and tibia were involved as well as for patients in whom the femoral neck was involved.

Diagnostic Problems in Children's Orthopaedics. The Committee on Pathology of The American Academy of Orthopaedic Surgeons presented the case histories, the roentgenograms, and the photomicrographs of eleven patients whose lesions were unusual or confusing. Included among these conditions were the following: Hand-Schüller-Christian disease in a young child; chondroblastoma of the capital femoral epiphysis; giant-cell tumor of the trochanteric region in a seventeen-year-old girl; Ewing's sarcoma in two patients; osteogenic sarcoma in four patients (each of these four tumors exhibited different pathological characteristics); eosinophilic granuloma of the mandible and mastoid; and osteoid osteoma in the lumbar spine in a young child. Descriptive material explaining the reasons for the particular diagnosis was available.

Temporary Surgical Deafferentation in the Treatment of Spastic Hemiplegia. Lt. Col. Ernst Dehne, Lt. Col. Raoul C. Psaki, Jr., and Dr. Walter Treasnor of Letterman Army Hospital, San Francisco, California, described the improvements in the treatment of patients with spastic hemiplegia which have been obtained as a result of work in the various specialities. Advances in neurosurgery (Welch and Rosequey) now reveal a close correlation between the area of the brain affected and the degree of recovery to be anticipated. As a result of work in the field of physical medicine there are available refined techniques of elective re-education and selective protection of affected areas, the aims of these techniques being commensurate with the varying abilities of the patient during the different phases of recovery. Of particular value is the apparatus designed by Pearson which permits the identification percutaneously of small nerve branches by means of stimulation and nerve blocking with xylocaine.

The theory behind the orthopaedist's contribution to the treatment of patients with spastic hemiplegia is based upon the concept that the disturbance in function is dependent on two factors: (1) the amount of the deficit in the central nervous system and (2) the bombardment of the respective motor centers by volleys of afferent nerve impulses. Temporary denervation of the preponderant muscles permits re-education of their antagonists. The gain that is obtained during this period is not lost after the function of the denervated muscle returns. It is felt that this gain is the result of the interruption of the afferent volleys which originate in the spastic muscle.

This method of treatment is still in the early stages of its development. The results obtained to date in the equinus foot have been excellent, but those achieved in the upper extremity have been limited to improvement in the position of the extremity. There is as yet no reason to expect that the procedure will result in any significant return of the finer functions of the hand.

Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades. Dr. Anthony F. DePalma of the Jefferson Medical College, Philadelphia, Pennsylvania, presented a study of the changes which occur in both the sternoclavicular and the acromioclavicular joints during each decade of life. The gross specimens consisting of 116 sets of joints, beautifully mounted in plastic, were exhibited. These specimens comprised the material upon which the statistical data presented in this study were based.

The sternoclavicular joint deteriorates very slowly. Although occasionally degeneration appears in the fourth, fifth, or sixth decade, in most cases severe alterations are not apparent until the seventh decade. From the seventh to the tenth decades, progressive deterioration in the interarticular disc occurs, and concomitant severe alterations develop in the articular surfaces of both the clavicle and the sternum. As long as the disc maintains its integrity, generalized disruption of the joint does not occur. However, as soon as the disc undergoes deterioration and fails to serve as a protective mechanism, the joint deteriorates rapidly. These observations explain why few patients have painful lesions involving the sternoclavicular joint.

The acromioclavicular joint deteriorates relatively early in life. The degenerative changes in the disc and in the articular surfaces of this joint virtually reach their maximum in the fifth decade, the only further changes being a slight increase in deformation during the eighth and ninth decades. Because the alterations which occur in the acromioclavicular-joint disc are severe and because the mechanics and anatomical arrangement of this joint are far inferior to those of the sternoclavicular joint, clinical manifestations are encountered more frequently in this joint than they are in the other.

Conservative Treatment of Club Feet. Dr. William Minor Deyerle and Dr. Carl J. Roncaglione of the Medical College of Virginia, Richmond, Virginia, stressed the importance of the continuity of treatment, this treatment being started with the application of a corrective plaster cast during the first few days of the patient's life in the manner advocated by Kite. It was emphasized that after the adduction and varus deformities of the fore part of the foot have been overcorrected, the foot must be returned to the mid-line position; overcorrection in dorsiflexion can then be started. When all components of the club-foot deformity have been overcorrected, the foot should be held in an overcorrected position for a minimum of eight weeks. Following final removal of the casts, Denis Browne splints, placed on the shoes, are used to maintain correction until the child starts to walk and can bear weight normally. If at any time during the follow-up period there is the slightest evidence of a recurrence of the deformity, new corrective casts should be applied. Any doubt about whether or not a recurrence is developing should be resolved by assuming that it is present. In charity cases, placing the patients in a boarding home greatly facilitates their care and follow-up.

Blind subcutaneous surgery should be avoided. In cases in which conservative treatment fails repeatedly the authors advocate the performance of a radical open exploration through an incision which follows the course of the posterior tibial tendon. At the exploration the presence of a large amount of scar tissue and of other deforming factors such as anomalous tendons may be demonstrated. The following structures should be excised: the laciniate ligament, the deltoid ligament, the scar tissue between the talus and calcaneus, and the scar tissue between the talus and scaphoid. The posterior capsule of the ankle and subtalar joints should also be excised, under direct vision, and the posterior tibial tendon should be cut. The heel cord is then lengthened under direct vision, and any anomalous tendons are divided. The tourniquet must be removed before closure to insure that the circulation to the foot is adequate when the foot is in the corrected position.

It is important that the same orthopaedist treat the patient from the beginning to the end of treatment. A multiplicity of opinions usually results in complications and may unnecessarily prolong the treatment.

The exhibit presented a study of forty-eight patients treated at the Medical College of Virginia. Eighteen of these patients served as controls. They had been treated by various members of the teaching staff, but none had been treated entirely by one orthopaedist. The remaining thirty patients had all been treated in the same manner. Continuity of treatment over a period of eighteen months had been assured by having all decisions as to continuation or discontinuation of treatment made by one orthopaedist.

The average length of time that casts were worn was 29.6 months in the control group and 4.9 months in the group in which continuity of care was maintained.

Subtotal Patellectomy with Burial of Anterior Cortex. Dr. Bernard Diamond of Waterloo, Iowa, described a procedure which may be used whenever patellectomy is required in a patient with an intact quadriceps mechanism. Through a medial utility-type incision the patella is removed entirely except for the anterior cortex, and the raw surface of the remaining nubbin of bone is covered by flaps made from the surrounding synovial membrane.

Before closure of the wound the joint is flexed in order to be sure that the synovial sutures will not break or pull out. The procedure is especially valuable in knee joints in which immobilization may lead to loss of motion.

The advantages claimed for this procedure are: (1) early motion is possible; (2) a smooth gliding surface

is provided for the extensor mechanism on the femoral condyles; (3) the leverage of the quadriceps is better than with total patellectomy; (4) the femoral condyles are protected from "bumping" by the remaining portion of the patella; and, (5) the patient likes to keep a part of his knee cap, no matter how small.

This procedure had been done on thirteen knees during the past three years for such lesions of the patella as old fracture, chondromalacia, arthritis, and recurrent dislocation. In one patient a total patellectomy had been done on one side and a subtotal removal of the patella on the other. The knee treated by the latter procedure had regained motion more rapidly than had the other, and the patient had found that bumping this knee caused less discomfort.

Sterile Draping Procedures for Extremity Surgery. Dr. Murray E. Gibbens, Dr. Thomas J. Coleman, and Dr. Alexander S. Barnett of the Veterans Administration Hospital, Denver, Colorado, presented five photographic charts which illustrated, step by step, procedures for the sterile draping of shoulder, elbow, forearm, hand, hip, thigh, knee, leg, and foot for orthopaedic surgical procedures. They had been made as part of an effort to standardize draping techniques in the authors' hospital and as a guide to be used in the resident training program.

The techniques that were shown are considered a part of the orthopaedic surgeon's basic training; they are quite similar to those used elsewhere.

Bipedal Rats and Mice; New Laboratory Animals. Dr. Charles W. Goff and Dr. Walter E. Landmesser of the Yale Medical School, New Haven, Connecticut, and Newington Home and Hospital for Crippled Children, Newington, Connecticut, had performed amputations of the fore limbs just above the elbows and of the tails of three-day-old Wistar white rats and DBA gray mice under hibernation anaesthesia, thus repeating and extending the work of Kickmeyer (1895), Field (1901), Colton (1929), and Slijper (1942).

The white rats were found to be very adaptable, developing changes characteristic of a biped. These included a single-footed gait, enlargement of the distance between the two hind feet, lengthening of the femur, shortening of the tibia, broadening of the ankle, and a knock-knee posture, with bending of the upper end of the tibia, which consistently followed the law of cubes. In addition, the toes spread further apart, the animal became plantigrade, and the spines developed an anterior curve comparable to a kyphosis in man. The skulls became shorter, and the spinous processes seemed to be less angulated, but the lordosis did not increase.

The mice, in contrast to the rats, became hoppers, a devolutionary change in the direction of the marsupialia (kangaroos).

If the adaptations which were found in these animals should ever occur as a result of a mutation, they would constitute an example of Simpson's theory of "quantum evolution" (1951), representing a great advance for the rats but a reversion for the mice.

These animals, the rats in particular, can be used to excellent advantage for surgical experimentation on posture, for the study of scoliosis, and for the investigation of the effects of nutrition on the growth of animals which are in the erect position.

The total cost of producing each animal and of maintaining it for a year was fifteen dollars, including the overhead.

Ten-Year Survival of a Patient with Osteogenic Sarcoma of the Tibia with Pulmonary Metastasis. Dr. Raphael R. Goldenberg of St. Joseph Hospital, Paterson, New Jersey, presented the roentgenograms and color transparencies of the photomicrographs of the primary tibial and metastatic pulmonary lesions of a seventeen-year-old girl with osteogenic sarcoma who had survived for ten years after amputation.

Following a preliminary biopsy, a mid-thigh amputation had been done in 1945. The patient had been well for three years. Then, in 1948, a solitary pulmonary metastasis had been discovered, and a lobectomy had been done by Dr. R. H. Overholt. The roentgenograms made in November 1955, ten years after the amputation and seven years after the lobectomy, showed no evidence of recurrence.

The Use of the Conditioned Response in Bracing. Dr. Herbert E. Hipps of Waco, Texas, demonstrated a number of braces designed to correct deformities by establishing conditioned reflexes.

In an article published in *The Journal of Bone and Joint Surgery* in 1954, a back-knee brace of this type was described. The purpose of this brace was to break the habit of hyperextending the knee in children who had the muscular ability to prevent it. This was accomplished by means of a long brace with a piece of elastic webbing strap behind the knee on which was placed a small felt pad from which a pin projected about two millimeters. When the knee was hyperextended, the skin came into contact with the pin and the children soon learned not to hyperextend their knees. So successful was this brace that similar braces, also utilizing this principle, were designed to treat other conditions.

Among the conditioned-reflex braces demonstrated at the exhibit were the back-knee brace and braces designed to correct round-back, sway-back, and neck-flexion deformities. Also demonstrated was a brace

designed to eliminate the substitution reaction in patients with weak finger flexors following poliomyelitis. These patients develop the habit of dorsiflexing the wrist instead of flexing the fingers and, therefore, do not regain all possible strength in the flexors.

Of particular interest was the scoliosis harness brace. It was emphasized that scoliosis should be detected early, by means of roentgenograms made with the patient standing, and that if it is detected early, the use of the conditioned-reflex scoliosis harness brace is a most effective method of treatment. The indications and contra-indications for the use of this brace were described and the techniques for applying it were demonstrated by pictures and photographs and by a brace mounted on a torso.

The use of the conditioned-reflex brace to treat abnormalities has proved to be most effective and efficient, and it is the hope of the author that others will adopt this type of brace and, furthermore, will use it to treat conditions to which it has not yet been applied.

The Posterolateral Approach for Cancellous Bone Grafting in Non-Union of the Tibia. Dr. Kenneth G. Jones and Dr. James Booth of Little Rock, Arkansas, presented the indications for and the advantages of using cancellous-bone grafts for non-union of the tibia inserted through the posterolateral approach. The technique for this approach was described, and reproductions of the roentgenograms of ten cases of non-union treated by this procedure were presented. The results of twenty-seven operations which had been performed on twenty-six legs were as follows: Twenty-two patients had gained complete stability of the involved extremity. Two patients' legs were stable when supported by means of a long leg brace with laced cuff. Two other patients had been lost to follow-up at seven weeks. In one patient the first operation had failed, but stability had been obtained by a second grafting procedure (this patient is included in the group with successful procedures mentioned previously).

All of these twenty-six patients had had previous operative procedures on the involved extremity. At some time thirteen of the legs had been infected. At the time of bone-grafting through the posterolateral approach some degree of drainage from the front of the leg had been present in eleven cases. This drainage had been circumvented by the posterolateral approach, and stability of the leg without infection of the bone graft had been obtained in nine of these patients. In the other two infection occurred. In one the graft had become grossly infected, and drainage from the leg had continued with sequestration of a portion of the graft. When this patient was lost to follow-up four months after operation, the leg appeared to be stable clinically. In the second of the two cases in which the graft had become infected, stability of the leg had been obtained without initial infection, but a recrudescence of the original osteomyelitis had developed after three years. In sixteen cases the grafts were autogenous iliac bone, and in nine they were homogenous washed and autoclaved vertebral bodies. In two legs a mixture of these two grafting materials had been used.

The indications for, the advantages of, and the technique of this operative procedure were described in the December 1955 issue of *The Journal of Bone and Joint Surgery*. It is the exhibitors' opinion that this procedure may be used to advantage in most patients with non-union of the tibia and especially in patients in whom infection has been or is present.

A Study of the Use of Pelvic Tilt During Standing and Walking to Induce Active Correction of Scoliotic Curves. Dr. William Norman Jones and Dr. Paul L. Norton of the Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts, demonstrated that some reduction of a thoracic scoliosis will be obtained if the spine is so positioned that it will be corrected actively by the patient's efforts to maintain the erect posture. This position is obtained by the use of a spica which abducts one hip and a shoe lift which adducts the other.

When this apparatus is used, the position of the pelvis is controlled by the position of the limbs while the position of the lumbar spine and consequently of the thoracic spine as well is controlled by the torso portion of the brace.

Roentgenograms were exhibited of four patients who had been treated with this device for periods of from two to four months. In one child with idiopathic scoliosis and in one with congenital scoliosis, apparent satisfactory improvement of a thoracic curve had been obtained. In another child with idiopathic scoliosis there had been no improvement, apparently because of ineffective use of the apparatus. The roentgenograms of the fourth child demonstrated the effectiveness of this pelvic-tilt brace in controlling a lumbar curve at least while the patient was standing.

In this study a leather spica with a hip joint permitting flexion and extension had been used. All the children were very active and the older ones attended school normally.

Lower Extremity—Temporary Training Prosthesis (Pylon). Dr. James F. Kurtz, Dr. Raymond O'Brien, Dr. M. D. Flank, and Dr. Erma A. Smith of the Veterans Administration Hospital, Hines, Illinois, demonstrated the fabrication and fitting of temporary prostheses for training the lower-limb amputee.

Surgery for Gout. Dr. W. A. Larmon, Dr. J. F. Kurtz, Dr. E. Millar, Dr. M. M. Montgomery, Dr. E. M. Barton, and Dr. R. M. Poske of the Hines Veterans Administration Hospital, Hines, Illinois.

stressed the destructive character of tophaceous gout, emphasizing that it destroys the soft tissues as well as the bones and joints. In this exhibit the microscopic invasion of bone as well as the destructive character of the disease was demonstrated in several patients, and illustrations of the surgical removal of tophi involving both soft tissue and bone were shown, along with follow-up photographs. It was urged that destructive lesions may be avoided if surgery is performed early in conjunction with the use of appropriate uricosuric agents. The removal of tophi decreases the total uric-acid content of the body and, thus, makes the use of the uricosuric agents more effective.

The principles of the surgery involved were discussed, and the appropriate techniques for performing this surgery were described.

Congenital Dysplasia and Dislocation of the Hip. Dr. Paul E. Lipscomb and Dr. L. E. Harris of the Mayo Clinic and Mayo Foundation, Rochester, Minnesota, presented a method of diagnosing congenital acetabular dysplasia in patients with or without dislocation of the hip. Too often the diagnosis of this condition is not made until the child has reached the age of weight-bearing or until the condition is evidenced in adult life by the presence of a painful hip. By the routine use of the hip-abduction test during the examination of newborn and older infants, the condition may be diagnosed early. Simple effective treatment may then be carried out by means of the Frejka pillow splint.

The exhibit demonstrated with photographs and models the method by which the abduction test is used to determine the presence of congenital disorders of the hip. It presented the salient features of congenital acetabular dysplasia as they appear on roentgenograms made before and after treatment, and it demonstrated the design and application of the Frejka pillow splint.

Functional Fixation of Intracapsular Fractures of the Hip. Dr. William K. Massie of Lexington, Kentucky, presented an exhibit on the treatment of intracapsular fractures of the hip. The purposes of this exhibit were as follows:

1. To reiterate the importance of the stresses exerted on the hip joint in the frontal plane, as described by Inman in *The Journal of Bone and Joint Surgery* in 1947, and to stress the importance of placing the proximal fragment in the valgus position, as demonstrated by Pauwels in 1935.

2. To demonstrate a sliding nail which has been found effective when applied in the optimum position and to outline the technique of using this nail.

3. To compare, by means of statistics and photographs, the results obtained in thirty displaced intracapsular fractures fixed in the optimum position with the sliding nail of the author's design with the results obtained in eighteen displaced fractures also fixed in the optimum position, but by means of other appliances.

Intracapsular fractures of the hip, like fractures of the carpal scaphoid, encompass problems, both mechanical and vascular, which are not clearly appreciated by many who endeavor to treat them. The author believes that every non-union is the result of one or more of the following: (1) technical failure; (2) failure to maintain adequate and persistent follow-up until union is complete; and (3) lack of patient cooperation. All intracapsular fractures will heal if they are adequately reduced and if immobilization of the fragments is maintained until healing ensues. The object of the treatment of this fracture, then, is to so fix the fragments that even with lack of cooperation on the patient's part the fracture will remain undisplaced and healing will ensue.

Most fractured hips are relatively stable if the fracture has been reduced anatomically and the fragments are held in place by means of a fixation device. However, if the stress on the fracture becomes excessive, as may occur even with occasional accidental weight-bearing, the coefficient of shear will exceed the coefficient of friction, and the fracture becomes unstable. It is the author's opinion that every fracture which fails to unite is unstable for this reason.

Adequate reduction implies *overcorrection of the proximal fragment into a valgus position*. The fracture line is thus made as nearly perpendicular to the weight-bearing axis and to the direction of the medial trabeculations as is possible. The fragments *must be impacted forcefully* at the termination of the operative procedure, for such impaction greatly increases the coefficient of friction and almost eliminates the coefficient of shear. A stable leg is thus obtained before the patient leaves the operating room; no normal force subsequently applied to the hip will distract the fragments. Adequate fixation is, of course, essential. It seems that this can best be obtained by inserting a telescoping nail as far as the subchondral bone of the femoral head at an angle of 155 degrees with the femoral shaft so that the nail rests on the calcar femorale. The assembly is fixed to the lateral portion of the femoral shaft with a short two-or-three-hole plate. In the lateral roentgenogram, the nail should appear to be slightly posterior to or in the mid-line.

In twenty-nine of the thirty consecutive cases in which the fragments were immobilized by the sliding-nail technique, bone union occurred. In the remaining case the nail, which had been improperly placed, tore out of the head of the femur within two days of the operation. In eighteen cases in which the fragments had been placed in the overcorrected position and then fixed at this 155-degree angle by means of various rigid-nail techniques, there was a 20 per cent rate of non-union. The one variable factor in these two series of patients, all treated by the same operator, was impaction. Impaction could be attained in the group in which the sliding nail was used but could not be attained in the group in which a rigid nail was used.

Osteotomy-Bunionectomy for Severe Hallux Valgus. Dr. C. Leslie Mitchell, Dr. Joseph L. Fleming, Dr. Richard H. Allen, Dr. Christopher C. Glenney, and Dr. Glenn A. Sanford of the Henry Ford Hospital, Detroit, Michigan, presented an exhibit on the treatment of severe hallux valgus by osteotomy and bunionectomy. This exhibit consisted of three sections. In the first section the history of bunion surgery was given, and diagrammatic black-and-white transparencies were shown to illustrate the over-seventy operative procedures of which descriptions had been found in the literature. The transparencies were grouped according to the basic operative principle involved and included five examples of soft-tissue surgery, ten examples of soft-tissue surgery combined with exostosectomy, five examples of soft-tissue surgery combined with exostosectomy and sesamoidectomy, twenty-one examples of arthroplasty, eleven examples of osteotomy, three examples of arthrodesis, and two procedures that could not be fitted into the preceding arbitrary classification.

In the second section of this exhibit color transparencies, with accompanying anatomical drawings, were shown to illustrate the operative technique which has been used in the treatment of severe hallux valgus at the Henry Ford Hospital during the past twenty-five to thirty years. Color transparencies of graphs showing the end results and related factors were also presented. In the third section short case histories were given, and black-and-white and color transparencies of typical preoperative and postoperative photographs and roentgenograms were shown. Several of these transparencies illustrated factors which had been found to have an important influence on the end result.

The operative procedure used at the Henry Ford Hospital is as follows: Following an osteotomy of the neck of the first metatarsal, the distal fragment is shifted laterally and then tilted so that the varus deformity of the first metatarsal is decreased. An exostosectomy is also performed, followed by plastic repair of the medial capsule, to correct the valgus deformity of the first toe.

Fifty-nine patients upon whom one hundred such procedures had been done were examined after an average follow-up period of eight years. Eighty per cent of the results had been reported as satisfactory by the patients, while 82 per cent had been rated as excellent or good by the surgeon. The significant finding in this study was that a good result was secured if there was a decrease in the varus deformity of the first metatarsal and little or no decrease in the range of motion of the first metacarpophalangeal joint. The presence of metatarsalgia after operation was not related to the amount of shortening of the first metatarsal but was related to the dorsal-plantar position of the head of the first metatarsal. In the patients in whom the first metatarsal head was dorsiflexed, weight-bearing was increased on the heads of the second and third metatarsals and metatarsalgia tended to develop or to become aggravated, while the converse was true in patients in whom the head was in a plantar position.

Interstate Auto Crash Injury Research. Mr. John O. Moore of the Cornell University Medical School, New York City, presented an exhibit on the findings of the Automotive Crash Injury Research project at Cornell University Medical School. As a result of this project injuries resulting from passenger-automobile accidents have been incorporated into the province of preventive medicine.

Stressing injury prevention rather than accident prevention, Automotive Crash Injury Research utilizes the public highway as a laboratory for research, securing on-the-spot accident information through the organized participation of traffic enforcement groups and obtaining medical data, with the assistance of local health departments, through the cooperation of attending physicians and their medical societies. The information thus obtained is coded, evaluated, and analyzed and is then used as the basis for technical reports. These reports are available to such interested groups as medical and public health organizations, automobile designers, engineers and manufacturers, safety councils, and insurance groups.

Utilizing methods and techniques developed during twelve years of crash-injury research in the aviation field, the automotive research group has, in the less than three years of its existence, already identified the types, frequency, and gross causes of the injuries which result from automobile accidents. It is now proceeding to identify the specific items in automobiles which cause injury or death. A basis will thus be provided for evaluating car designs and for assessing the probable efficacy of improvements contemplated by manufacturers.

The design improvements envisioned are intended to "package" the passenger so as to prevent or minimize the occurrence of injury, disfigurement, or death as a result of accidents. An improvement, comparable to the excellent results already obtained in aviation through safer designs, is expected to follow the attainment of this objective.

The project is sponsored by the Commission on Accidental Trauma of the Armed Forces Epidemiological Board and is supported by funds from both the United States Department of Public Health and the Office of the Surgeon General, Department of the Army. Grants for independent research have also been provided by the Chrysler Corporation and the Ford Motor Company.

Resources for the Orthopaedic Surgeon Working with Crippled Children. The National Society for Crippled Children and Adults of Chicago, Illinois, presented an exhibit on the resources which they make available to the orthopaedists who work with crippled children, to the families of these children, and to the communities in which the children live.

The following resources were listed as examples of the assistance which the National Society can offer: (1) library and visual-aid material to be used in the treatment of children with speech disorders and other special problems which are due to such crippling conditions as cerebral palsy; (2) models and diagrams of equipment which may be used in the home, in treatment centers, and in schools; (3) community consultation services to help with planning for crippled children; and (4) referral services to provide information on such organizations as hospitals, treatment centers, and camps.

American Orthopaedic Surgeons. Dr. H. Winnett Orr and Dr. Frank P. Stone of the Nebraska Orthopaedic Hospital, Lincoln, Nebraska, presented a collection of portraits of American orthopaedic surgeons. A special effort has been made to include in this collection the "pioneers" from throughout the country. About 250 names were listed in the catalogue, but this included many men who were shown in group photographs only.

An outstanding example of a group picture was the photograph taken at the meeting of The American Orthopaedic Association in Detroit in 1915. In this picture there appear many of the older men who were prevented by World War I from attending another such meeting. Among others shown in this group are: Shands, Taylor, and Sayre of New York; Painter, Lovett, and Osgood of Boston; McKenzie of Toronto; David, Wilson and Rugh of Philadelphia; Freiberg of Cincinnati; Stern of Cleveland; Silver of Pittsburgh; Ridlon, Ryerson, and Blanchard of Chicago; Packard of Denver; and Griffith of Kansas City.

Only a few of the great men of American Orthopaedics were missing from this "gallery", and an attempt was made at the meeting to repair these omissions and to correct the catalogue in order to make it of permanent historical value.

Fractures of the Distal One-Third of the Radial Shaft: Mistakes in Management. The Piedmont Orthopedic Society of Columbus, Georgia, presented an analysis of forty-one cases of isolated fractures of the radial shaft which had occurred at the junction of the middle and distal one-thirds of the bone. Thirty-eight of the patients had been initially treated by closed reduction, a procedure which had been successful in only three instances. Of the thirty-five patients in whom the procedure had been a failure, seven had refused further treatment and twenty-eight had been treated by open reduction, twenty-one during the first four weeks following the occurrence of the fracture and seven after more than four weeks. In the twenty-one patients treated early by open reduction, various types of internal fixation had been used, including Rush pins, Küntscher nails, multiple Kirschner wires, and bone plates. The results in this group were satisfactory in fourteen instances and unsatisfactory in six. In the seven patients operated upon later and in two of the above patients, upon whom further operations had been performed, the results were satisfactory in four instances and were unsatisfactory in five. The operative treatment used in this group varied, including bone-grafting combined with intramedullary fixation, the insertion of double onlay bone grafts, and resection of the distal portion of the ulna. Analysis of the unsuccessful results in both of the groups of patients treated by open reduction revealed the following reasons for failure: delayed union, two cases; non-union, three cases; subluxation of the ulna at the distal radio-ulnar joint, six cases. Serial translite reproductions of roentgenograms from selected cases were used to emphasize the difficulties encountered in the management of this fracture.

The exhibit presented diagrams depicting the deforming factors which are present with this fracture, including the pulls of the brachioradialis, the pronator quadratus, and the extensors and abductor muscles of the thumb. Subluxation of the ulna at the distal radio-ulnar joint was emphasized as an important reason for failure.

The conclusions drawn from this series of cases were as follows: (1) This fracture is, in the words of Willis Campbell, "the fracture of necessity" and should be treated by early open reduction with solid internal fixation. (2) If the fracture is treated belatedly, namely after failure of closed reduction but not more than four weeks following the occurrence of the fracture, serious consideration should be given to bone-grafting as well as to the use of internal fixation. (3) In the patients in this series treated after the first four weeks, the most successful treatment appeared to be bone-grafting combined with solid internal fixation and resection of the distal end of the ulna.

Treatment of Grade IV Fracture-Dislocation of the Hip. Garrett Pipkin of Kansas City, Missouri, presented an exhibit on Grade IV fracture-dislocation of the hip. According to Stewart and Milford this injury is a "dislocation with a fracture of the head or neck of the femur". Although this injury used to occur only rarely, usually in workers in heavy industry, it is now more common due to traffic accidents. The material for this analysis was obtained from the pooled experience of a correspondence group and of the orthopaedic surgeons of Greater Kansas City. A total of twenty-five hips in twenty-four patients had been treated. The length of the follow-up in these cases had ranged from six months to eighteen years.

The following types of injury may occur: (1) dislocation with fracture of the femoral head caudal to the fovea centralis; (2) dislocation with fracture of the femoral head cephalad to the fovea centralis; (3) disloca-

tion, fracture of the femoral head, and fracture of the femoral neck; and (4) dislocation, fracture of the femoral head, and fracture of the rim of the acetabulum.

The methods of treatment used in this series were closed reduction, open reduction, open reduction after excision of a blocking fragment, and various salvage procedures. The series is too small for a statistical analysis of the results to be made, but it would appear that the best results were achieved by the early performance of closed reduction of both the dislocation and the fracture, followed by a suitable period of immobilization or traction.

The Oblique Rotational Osteotomy in Combined Rotational and Angular Deformity. Dr. T. Gordon Reynolds and Dr. William A. Scharffenberg of the College of Medical Evangelists, Los Angeles, California, displayed six working models of osteotomized bones which could be arranged to simulate combined rotational and angular deformities such as might be found at the knee or hip or in the shafts of long bones. By means of these models it was shown that an appropriately placed oblique osteotomy can be used to correct simultaneously both rotational and angular deformities.

In the performance of such an osteotomy it is obviously necessary to make the cut (1) at the proper angle, (2) in the right direction (right or left) and (3) in the proper plane with relation to the direction of the "apex" of the bowing.

The main part of the exhibit consisted of a presentation of the methods for determining the correct localization of the osteotomy.

It was recommended that the surgeon rehearse the operation with a crooked stick, a bent candle, or modeling clay.

Following an oblique rotational osteotomy the cut surfaces remain in contact with each other, a feature which is a great advantage, for union is thereby facilitated. A step, a V, or a hinge can often be left at one end of the osteotomy to promote stability.

Synovial and Fat-Pad Changes of the Knee Joint. Dr. M. D. Sachs, Dr. W. H. McGaw, Dr. R. Rizzo, Dr. A. Buergler, Dr. G. Furey, and Dr. P. Berg of the Veterans Administration Hospital and Western Research Medical School, Cleveland, Ohio, exhibited transparencies of photographs, photomicrographs, and pneumoarthrograms, illustrating the changes which are encountered in the synovial membrane and fat pad of the knee joint. The exhibit was based upon data obtained from over 200 synovial biopsies performed during routine arthrotomy of the knee. The synovial changes which occurred in 80 per cent of the patients studied were due to different forms of "internal derangement"; these changes differed from each other in degree rather than in type. In approximately 20 per cent of the patients more specific types of synovitis had occurred, including acute traumatic synovitis, septic arthritis, gout, chondromatosis, osteochondromatosis, pigmented villonodular synovitis, neuropathic synovitis, tuberculosis, and rheumatoid arthritis.

The changes which had occurred as a result of all of the above conditions were illustrated. It was felt that pneumoarthrograms have a unique value as a method of establishing a diagnosis in cases of fibrosis of the infrapatellar fat pad, osteochondrosis of the patella, synovial chondromatosis, and pigmented villonodular synovitis; they are also valuable in cases of meniscal injury. Real accuracy in diagnosing synovial lesions can only be obtained by a careful study of (1) the patient's history, (2) the findings of a physical examination and of laboratory studies, (3) roentgenograms, including pneumoarthrograms, and (4) histological sections.

Functional Bracing of the Arm. Dr. E. R. Schottstaedt, Dr. Claude Lambert, Dr. Vernon Nickel, Mr. George Robinson, Dr. Frederick C. Bost, Dr. Loren J. Larsen, and Mr. Lester Carlyle of the Franklin Hospital, San Francisco, California, and University of Illinois, Chicago, Illinois, presented an exhibit on functional bracing of the arm. The various types of functional upper-extremity braces in use at the present time were shown and the importance of the team approach for the successful prescription of apparatus and for the training of the patient was emphasized. The exhibit was sponsored by the National Foundation for Infantile Paralysis. (See Functional Arm Bracing by Dr. E. R. Schottstaedt and Mr. George Robinson in the June and July 1956 issues of *The Journal.*)

Educational Activities of the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc. Mr. Lester A. Smith of Washington, D. C., described in his exhibit the following projects designed to further the education and training of the orthotist and prosthetist:

1. Examinations devised to test the skill and knowledge of the bracemaker and artificial-limb maker.
2. An apprenticeship training system in which the completion of a series of work projects and academic instruction in a number of subjects are required.
3. A brace dictionary sponsored jointly by the Board and by the Orthopedic Appliance and Limb Manufacturers Association. This dictionary, now in preparation, will index the various braces under all the names by which they are known in this country. (The proposals of the editors for this work have been described in the April issue of *The Journal of Bone and Joint Surgery.*)

4. Teaching materials, including selected reprints from the *Orthopedic and Prosthetic Appliance Journal.*

The exhibit presented a description of the organization of the Board, emphasizing that under its by-laws three members of the seven-man Board of Directors must be orthopaedic surgeons, elected after nomination by the executive committee of The Academy.

Determination of Radioactive Phosphorus Pickup in the Upper Femur. Dr. Irwin Stein, Dr. William Serber, and Dr. Martin L. Beller of the Albert Einstein Medical Center, Southern Division, and Philadelphia General Hospital, Philadelphia, Pennsylvania, demonstrated a method for determining variations in the circulation of the head and neck of the femur. Thirty-five patients had been studied, including twenty-three with subcapital fractures (two of these patients had bilateral fractures, which had occurred following electroshock therapy), nine with transverse fractures, one with a fracture at the base of the femoral neck, and two with intertrochanteric fractures.

The material injected in these patients was radioactive phosphorus (P^{32}). This material was chosen because it is more widely used by physicians than is any other radioactive material. Furthermore, when used in the tiny amounts (200 microcuries) that were required for this study, it is relatively safe.

Since this material, when injected intravenously, is transported through the body by means of the blood stream, demonstration of its course within the body will provide information concerning the subject's circulation. Radioactive phosphorus is a bone seeker, however, and there will be a rather rapid exchange with the phosphorus in the bone. Therefore, if the condition of the circulatory system is to be related to the course of the phosphorus, the readings must be made within a very few minutes of the time of injection. The exhibitors feel that the optimal time is within the first six minutes.

This material must be used under the supervision of a physician who is qualified to handle radioactive materials. Furthermore, it must not be used in subjects who are still growing.

The many technical problems with which the authors were faced in this study were finally resolved by the use of the following apparatus:

1. A special six-inch Robinson-Severstone probe (this instrument can be autoclaved), which has the following advantages:

a. It is less than $\frac{3}{32}$-inch in diameter and, therefore, will pass easily into a cannula that is $\frac{7}{64}$-inch in diameter or into the cannulated portion of a modified Smith-Petersen nail.

b. The probe can be placed within a metal cannula in order that the sensitive tip will be shielded. This insures that only material from the area to be studied will be picked up and that contamination by blood from other areas containing P^{32} will be avoided.

c. The probe is long enough to extend into the femoral head, even in an obese patient, through an incision which is only one inch long.

2. A shielded cable which is used to connect the probe to the count rate meter (this apparatus also can be autoclaved).

3. A proper count rate meter.

The routine used by the authors in the reduction and nailing of the intracapsular fractures and in the taking of the readings is as follows:

1. Reduction is carried out in a routine fashion and roentgenographic check on position is obtained with the patient fixed on the fracture table. A one-inch skin incision is made, and a blind nailing is carried out as follows in order that further interference with the circulation will not be caused by a capsular incision:

a. Under roentgenographic control a guide pin, $\frac{3}{32}$-inch in diameter, is introduced through the femoral neck into the head via a $\frac{3}{8}$-inch hole drilled in the lateral portion of the femoral cortex.

b. A cannulated Smith-Petersen nail is threaded over the guide pin and driven to within one-half of an inch of the articular surface of the head.

2. The guide pin is withdrawn and the six-inch Robinson-Severstone probe is passed carefully through the cannula of the nail and inserted into the tract in the head previously occupied by the guide pin.

3. Two hundred microcuries of P^{32} is injected intravenously.

4. Readings are made in the femoral head at intervals of thirty seconds for six minutes and alternating control readings are made in the muscle. An extra drill hole is made in the lateral femoral cortex in order that the medullary cavity may be accessible for additional control readings.

The studies shown in this exhibit are still in process. The author's preliminary interpretation of their findings is as follows:

1. Since the count obtained in six minutes is reasonably consistent and since for several minutes thereafter no appreciable increase in the number of impulses per minute occurs, it appears that P^{32} is carried primarily by the blood stream.

2. In patients with intracapsular fractures the head fragment shows consistently fewer impulses than does either the normal head or the femoral shaft on the fractured side. There is no change in the uptake of P^{32} in the femoral-head fragments of intertrochanteric fractures.

3. After some hours the number of impulses in the head fragments of intracapsular fractures increases. It is inferred that this is caused by additional deposition of P^{32} via tissue-fluid exchange since no part of the body is truly isolated.

The preliminary data has not yet been correlated with data obtained by an adequate clinical follow-up (the first reading was made in March 1953). Therefore, the authors cannot at this time give conclusions. Their method, they are certain, varies little from that of other workers, such as Boyd, and they are aware that similar work is being done currently by others. It is their hope that many more studies will be done, for the larger the number of cases studied, the more important the data will be and the more significant the conclusions derived from the data. It is, of course, obvious that the treatment of fractured hips involves many unsolved problems and also that there is no treatment which will substitute for proper reduction and fixation. This study presents one approach that may help to improve the treatment of these fractures.

The Architecture of the Upper End of the Femur. Dr. William J. Tobin of the Georgetown University School of Medicine, The Smithsonian Institution, and the Armed Forces Institute of Pathology, Washington, D. C., demonstrated, by means of microscopic sections and roentgenograms, the significance of the internal structure and external form of the upper end of the femur. Examples of such deformities as coxa valga and coxa vara were presented in the exhibit, and the trabecular patterns of the upper end of the femur were clearly illustrated. The importance of a knowledge of the internal architecture of the upper end of the femur was emphasized, and it was stressed that internal fixation should be inserted with the head in a valgus position and that this fixation should be placed so that it parallels the direction of the compression forces. The factor of femoral torsion was considered, and it was observed that the torsion occurs in the shaft and not in the neck of the femur.

For purposes of comparison, the femora of carefully selected animals and birds were shown to illustrate the variations in the internal structure of the upper end of the femur which may develop as a result of differences in physical build and methods of locomotion and as the result of other adaption factors.

Rehabilitation of Poliomyelitis Patients with Respiratory Involvement. Dr. Hart E. Van Riper of the National Foundation for Infantile Paralysis, New York City, presented a series of photographs illustrating the goals of the rehabilitation of patients with respiratory involvement; namely, freedom, in so far as possible, from dependence on mechanical respiratory aids; ability to take care of personal needs, such as eating, dressing, and ambulation; and social and economic independence according to individual interests and capacities.

J. A., a twenty-six-year-old housewife, was admitted to the Poliomyelitis Respiratory Center at the University of Michigan in August 1951. Within five days of admission her vital capacity had dropped to 250 cubic centimeters, the upper intercostals were completely paralyzed, both the upper extremities were almost completely paralyzed, and the lower extremities were weak.

J. A. was placed in a tank respirator shortly after admission. During the first week of illness use of the cuirass respirator, for very brief periods, was also started. Measurements of the vital capacity were made frequently in order to gauge the degree of improvement.

Functional training with assistive equipment was begun during the ninth week of hospitalization, and she received intensive physical therapy. After seventeen months of hospitalization, she was discharged. At this time she no longer needed any respiratory equipment; the muscles in the lower extremities ranged from good to normal; the right shoulder and arm were flail and the left shoulder was nearly flail; the muscles in the left arm varied from fair to poor.

She was fitted with an adapted Taylor back brace which was selected because it provided the stabilization of her shoulders necessary for her to use her hands and arms. The extension rods of this brace, which can be detached when a coat is worn, provide a fairly wide range of movement, which eliminates the need for a wheelchair with overhead slings. The brace does not constrict the chest or abdomen and is easy to put on and remove.

A year and a half after discharge (1954), J. A. was living a fairly normal life at home and was expecting a second child. When wearing the back brace she could do a little light housework and some gardening and could take care of some of her personal needs. She could not dress herself, however, or take care of her little boy. In addition to the brace, she was using an adapted telephone and a platform feeder to assist her left hand.

By the end of another year (1955) the range of J. A.'s activities, both inside and outside of her home, had increased. She still wore the back brace and used an adapted telephone, but the feeder had been discarded. She could take care of most of her personal needs, do light housework, mow the lawn, do some cooking, take partial care of both children, serve as alumnae counselor for her sorority, belong to a child-study group and participate in other community programs, and lead a normal social life. She could not dress herself, pick up or carry the baby, bathe or dress the baby.

AUDIO-VISUAL PROGRAM

Saturday Afternoon, January 28, 1956

Technique of Syme Amputation. Dr. Richard L. Shorkey, Beaumont, Texas.

Infant Hercules. Dr. Joseph Fleming, Detroit, Michigan.

Lesions of the Fibrocartilaginous Disc at the Wrist. Dr. H. M. Coleman, Toronto, Ontario, Canada.

Surgery of Gout. Dr. James F. Kurtz, Dr. William Larmon, and Dr. Edwin Miller, Hines, Illinois.

Anatomical Dissection of Congenital Club Hand. Dr. Ralph Lidge, Chicago, Illinois.

Technique and Follow-Up on Osteotomy Combined with Bone Graft for Non-Union of the Neck of the Femur. Dr. Marcus Stewart, Memphis, Tennessee.

Surgical Technique of Nailing Femoral Neck Fractures with Pugh Adjustable Nail. Dr. Willis L. Pugh, Evansville, Indiana.

Free Tendon Graft in a Race Horse. "Hickory Chuck." Dr. Garrett Pipkin, Kansas City, Missouri.

Prostheses in Children. Dr. Claude N. Lambert, Chicago, Illinois.

Prefabricated Casts. Dr. Leon Parker, San Francisco, California.

Extra-Articular Subastragalar Arthrodesis. Dr. Cameron B. Hall, Beverly Hills, California.

Monday Afternoon, January 30, 1956

Automotive Crash Safety Research at Cornell University. Mr. John Moore, New York, N. Y.

Poliomyelitis: Flexion and Extension Tenodesis in the Hand. Dr. C. E. Irwin, Atlanta, Georgia.

Tuesday Afternoon, January 31, 1956

Replacement of the Femoral Head with a Judet Prosthesis. Mr. K. I. Nisson, London, England.

Intramedullary Nailing of the Tibia. Prof. G. Küntscher, Schleswig, Germany.

Replacement of the Proximal Humerus and Distal Radius with Fibular Graft. Dr. H. H. Brindley and Dr. R. A. Murray, Temple, Texas.

Fibular Replacement of the Humeral Shaft. Dr. Joseph Reno, Bethlehem, Pennsylvania.

Wednesday Afternoon, February 1, 1956

Fractures of the Forearm. Dr. William Larmon, Chicago, Illinois.

Surgical Approaches to the Joints of the Spine and Sacro-Iliac. Dr. LeRoy Abbott, San Francisco, California.

EXHIBIT OF GADGETS AND NEW IDEAS

Pocket Medical Kit. Dr. Harry E. Barnett, Chicago, Illinois.

A Distensile Ligature Carrier. Dr. David M. Bosworth, New York, N. Y.

The Short Smith-Petersen Nails for Femoral Sub-Trochanteric Osteotomies in Children. Dr. Louis W. Breck, Dr. W. Compere Basom, and Dr. Morton H. Leonard, El Paso, Texas.

Traction Splint. Dr. Ronald M. Buck and Dr. Elza F. Butler, St. Joseph, Missouri.

Angled Guide Wire Director. Dr. William G. Durnin, Newtonville, Massachusetts.

Shoe Pad for Treatment of Calcaneal Spur. Dr. G. W. N. Eggers, Galveston, Texas.

Femoral Condyle Blade Plate—A New Device. Dr. Robert B. Elliott, Houston, Texas.

Newington Brace for Cerebral Palsy. Dr. Russell V. Fuldner and Dr. Josef Rosenberger, New Haven, Connecticut.

Surgical Leg Holder. Dr. Murray E. Gibbens, Denver, Colorado.

A Practical Pneumatic Tourniquet for Operating Room Use. Dr. Lot D. Howard and Dr. Philip J. Bailey, San Francisco, California.

Windsock Orthopaedic Surgical Drape. Dr. Clark H. Lauder, Jr., Pasadena, California.

Trephine Plug Spine Fusion. Dr. Duncan C. McKeever, Houston, Texas.

Compact Rack for Smith-Petersen Nails, Plates, Screws, and Drills. Dr. Justin C. McNutt, Bloomington, Illinois.

Driver-Extractor-Bender for Rush Wires. Dr. Justin C. McNutt, Bloomington, Illinois.

Treatment of Colles' Fracture. Dr. Joseph M. Strong and Dr. George W. Bennett, Elyria, Ohio.

ASSOCIATION OF BONE AND JOINT SURGEONS

Prepared by W. M. Deyerle, M.D., Richmond, Virginia

The Annual Meeting of the Association of Bone and Joint Surgeons was held in Minneapolis on March 22, 23, and 24, under the Presidency of Dr. Louis W. Breck. An excellent program had been provided by the committee, Dr. E. T. Evans and Dr. Richard Reiley. The meeting was held at the Hotel Nicollet.

Thursday, March 22, 1956

The meeting opened with a clinical session on hip surgery. Dr. Jones presented a series of patients who had had high oblique osteotomies for painful hips. Most had been relieved of their pain.

Dr. Rosendahl showed a series of hip fusions in which a tibial graft had been inserted into the acetabulum along the plane of a high oblique osteotomy.

Dr. Reily presented a series of patients with endoprostheses with some excellent results In one, an infection had developed; the prosthesis had been removed and the base of the neck had been inserted into the acetabulum. The result was excellent in spite of a short limb.

Arthroplasties of the Hip. Dr. W. H. Cole recounted the history of hip arthroplasty referring to the work of Wolff, Hoffa, Murphy, Sir Robert Jones, and Smith-Petersen. He felt that the only absolute indication for arthroplasty of the hip joint was bilateral ankylosis.

Fractures of the Hip. Dr. R. T. McElvenny stressed the importance of proper and adequate reduction and fixation of fractures in the hip. He felt that if delayed union could be detected within nine months an osteotomy might prevent the development of aseptic necrosis. He advocated the use of the Leadbetter osteotomy primarily in all subcapital fractures when no break is present. When impaction is possible, he favored it. He advocated the use of a threaded wire parallel to the nail to be inserted through the calcar femorale.

Femoral Epiphysiolysis. Dr. M. Beckett Howorth discussed epiphyseal coxa vara and reported an analysis of 250 cases. He had fixed the capital epiphysis with bone pegs inserted through a window in the femoral neck and felt the method to be superior to the use of a metal nail. Using this technique and with no attempt at reduction, he had had no aseptic necrosis and he stated that no further surgery had been indicated.

Posterior Dislocations of the Shoulder. Dr. Dana Street reported a series of ten patients with twelve posterior dislocations of the shoulder. In the acute severe cases complicated by compression fracture of the head or fracture of the humeral neck, he advocated open reduction. Following reduction he had treated the capsule as in the Bankhart procedure and in some cases where a defect existed in the anterior surface of the humeral head he had transplanted the subscapularis into this defect to act as a checkrein against further dislocation.

Reduction (Staple Fixation) of Beak Fracture of the Calcaneus. Dr. L. Greene presented a case of unusual fracture of the calcaneus treated by open reduction and staple internal fixation.

Congenital Dysplasia of the Upper End of the Femur. Dr. Fritz F. Teal presented a series of patients with congenital coxa vara, Grade IV. Whereas it is generally recognized that ossification of the femoral neck is complete by the age of sixteen, one of Dr. Teal's patients did not show complete ossification before reaching the age of twenty-four. Dr. Teal preferred the Brackett type of reconstruction of the hip at the age of eight or nine in order that he might later insert a prosthesis.

In discussion Dr. Wickstrom agreed with this plan of treatment but preferred to operate at the age of two or three years.

Syndrome of Spondylolisthesis and Tight Hamstrings. Dr. George Phalen had noted the coexistence of tight hamstrings and spondylolisthesis. He felt that the hamstring shortening resulted from the spine lesion for in one of three cases he had found and removed a neuroma in the filum terminale with an excellent result and the clearing up of the tight hamstrings. In one patient with advanced hamstring shortening he had lengthened the hamstrings with questionable improvement. In a third patient, a laminectomy and release of the cauda equina had resulted in marked improvement.

Dr. J. H. Moe in discussion agreed that irritation of nerves to the hamstrings induced by spondylolisthesis was responsible for the tight hamstrings. He had had similar patients.

The afternoon Scientific Session was closed by DR. E. T. EVANS who presented a paper entitled "Basic Statistics in Osseous Tuberculosis".

Friday, March 23, 1956

Etiology of Spondylolisthesis. DR. L. L. WILTSE discussed the etiology of spondylolisthesis. None of the theories so far advanced adequately explain this etiology. The author had studied the children of eleven patients who had spondylolisthesis. More than half of these had defects in the pars interarticularis as compared with an incidence of about 5 per cent in the general population. In one family of six children five had spondylolisthesis. He felt that from available evidence it would appear that defective pars interarticularis is a disease no trace of which is present at birth and which increases in incidence up to adulthood. Apparently, it is familial.

Paget's Disease—Its Implications and Complications. DR. JACK WICKSTROM discussed the etiology of Paget's disease. He then called attention to the well known capacity of Paget's bone to heal following fracture and to the hypercalcaemia and hypercalcinuria incidental to immobilization and bed rest in this disease. He felt, however, that healing was sometimes difficult in this condition and that prolonged recumbency was to be avoided if possible on account of the risk of kidney damage. A restricted calcium diet and forced fluids were important. He reported six cases of malignant degeneration in Paget's bone. Usually the neoplasm is osteogenic in character, although in one case fibrosarcoma was predominent. All terminated fatally.

In the afternoon session, DR. J. E. M. THOMPSON presented a simple and effective technique for the correction of undesirable angulation of recent fractures of the long bones. He divided the cast transversely, applied a strapped hinge on one side and a turnbuckle on the other. When the desired alignment was attained, the cast was reinforced by plaster, the hinge and turnbuckle having been removed.

Disability in Severe Fractures of the Calcaneus. DR. C. F. FERCIOT reviewed eighty-seven fractures of the calcaneus and found that 97 per cent of the patients had regained useful function. He urged immediate manipulative reduction under spinal anaesthesia or paravertebral block. Plaster fixation is continued for five weeks. Unstable joints are then treated by an operation to stabilize the damaged joint. He felt that triple arthrodesis was rarely indicated.

Dynamic Restoration of Muscle Imbalance in Recurrent Club-Foot. DR. E. M. BURGESS discussed etiological factors in club-foot. Many patients present gross muscle imbalance at birth. Frequently there are anomalous tendon insertions. He had found posterior transfer of the tibialis posterior tendon under the heel cord and into the peronaeus longus tendon with gastrocnemious recession to be an excellent surgical approach to the problem of muscle imbalance in the very young. Severe pes planus had not resulted. It had become increasingly apparent to him that the tendon surgery should be done during the early months of life, that is, in the pre-weight-bearing period at a time when passive overcorrection is easily accomplished, when bony deformity is absent, and when muscle patterns of action are easily changed.

Treatment of Idiopathic Scoliosis. DR. J. H. MOE discussed the treatment of idiopathic scoliosis. He pointed out that it does not necessarily progress during spinal growth, that no prediction can be made, and that every patient must be watched carefully during the growing period. Moderate well balanced curves which are not progressive do not require correction.

Adequate correction can be accomplished by the turnbuckle cast but the Risser localizer cast and the Milwaukee brace have proved more efficient and far more comfortable for the patient. The fusion area must be adequately determined. The entire primary curve including the neutrally rotated end vertebrae must be fused. The two main causes of loss of correction are short fusions and the presence of pseudarthrosis in the fused area. The incidence of pseudarthrosis decreases when the posterior articulations are included in the fusion and when grafts of the patient's iliac bone are added.

Saturday, March 24, 1956

Short Leg Problems. DR. W. P. BLOUNT discussed epiphyseal arrest and growth stimulation as a means of equalizing limb length. He felt that epiphyseal stapling should be employed in most cases. When equalization cannot possibly be obtained, the irrevocable arrest of Phemister-White is ideal.

End-result studies had shown that normal growth was resumed after removal of the staples. A stapled epiphyseal plate may appear so thin in the roentgenogram that one is apprehensive, but it will expand within six weeks after removal of the staples to twice its normal thickness. There is a concomitant brief spurt in growth.

He felt that bone stimulation on one side may well be combined with epiphyseal stapling on the other

when further shortening of the long limb would be undesirable. He noted that the effect of stimulation wears off in twelve to eighteen months, but restimulation at the same site is effective.

Shoulder Arthrodesis. Dr. R. E. Carroll presented a technique of shoulder arthrodesis which allows postoperative correction of the relation of the humerus to the glenoid without loss of contact. He maintains contact with a wire loop. He had had no failure of fusions. The wire is passed through a drill hole approximately parallel to the bicepital groove, through the neck and head of the humerus into a hole in the glenoid drilled in the upper anterior quadrant after removal of cartilage from the head and glenoid.

Temperomandibular Arthroplasty. Dr. Luis Iglesias presented a technique for temperomandibular arthroplasty which he had employed with excellent results in four cases of pyogenic arthritis, two of traumatic arthritis, and one of congenital origin. A pre-auricular incision was used. The zygomatic arch, the tubercle, the roof of the condylar cavity and the neck of the condyle and the coronoid process were resected. Following operation skeletal traction prevented reankylosis.

The annual banquet was held on the night of March 24.

Over 90 per cent of the members attended the meeting which was one to be remembered. Dr. George Duncan was elected President for the current year, Dr. C. Fred Ferciot, Treasurer, Dr. Jack Wickstrom, Secretary, and Dr. William M. Deyerle, Chairman of the Interassociation Relationship Committee.

THIRD CONGRESS OF THE SOCIEDAD LATINO AMERICANA DE ORTOPEDIA Y TRAUMATOLOGIA

The Third Congress of the Sociedad Latino Americana de Ortopedia y Traumatología was held in Mexico City, at the site of the University City, from January 13 to 20, 1956, under the Presidency of Dr. Alejandro Velasco Zimbrón. This event was carried out under the auspices of the Mexican Government with His Excellency Adolfo Ruiz Cortines, the President of the Republic, present at the inaugural session. Among those present at the Congress were Dr. José Luis Bado, from Uruguay, President, and Dr. Juan Farill of Mexico, Honorary President. Members gathered from all of the Latin American Republics. There were many orthopaedists from the United States of America, Canada, Spain, France, England, Belgium, Germany, and Portugal. In all there was a total of 650 present. Many men were accompanied by their wives.

The Scientific Program extended throughout the Congress. The official papers were on Legg-Calvé-Perthes Disease and The Treatment of Forearm Fractures. Two symposia were presented, one on Flat-Foot and the other on Traumatic Lesions of the Distal End of the Femur and Proximal End of the Tibia. An interesting round-table discussion was held on The Study and Modernization of Workmen's Compensation Laws for Industrial Accidents. Five short instructional courses were given: (1) Lumbosciatic Pain; (2) Traumatic Vascular and Nervous Lesions; (3) Treatment of the Spastic; (4) Skeletal Tumors of the Connective Tissue Series; and (5) Plastic Surgery in Orthopaedics and Traumatology. These courses were given by specialists from different Latin American countries. In addition, there were twenty-one lectures in the general assemblies given by well known Latin American, American, and European specialists. Almost seventy papers were presented and there was an excellent Audio-Visual Program. During the Congress, Scientific Exhibits of great interest were available, one of the most noteworthy being presented by the Oakland Naval Hospital, Oakland, California, showing the recent advances in artificial limbs and rehabilitation of the amputee. Also included was a commercial exhibit. Several operations were performed which were televised in color and many hospital rounds were made, among which were those at the Hospital de la Raza and at the Hospital Militar.

Social activities made possible by an organizing committee were available for guests and their wives; these included visits to places of interest in the city. Folk festivals, such as the Mexican Night and the festival of the Charros, were most enjoyable.

Scientific Sessions

Monday, January 16

Morning Session: Legg-Calvé-Perthes Disease

A number of papers were presented reporting the results of treatment, operative and non-operative, of Legg-Calvé-Perthes disease. The following observations were made:

1. The most important problem presented by this disease is its etiology and pathogenesis; there seem to be a number of causes which may act simultaneously. Racial predilection was insisted upon (white race). All were greatly impressed by the experimental work done by Ponseti and Trueta.

2. The treatment universally tried, which had proved its worth, was the withholding of weight-bearing while permitting movement. The length of this treatment led to the trial of other methods (surgical) which tended to shorten the course without danger; however, a longer period of observation is necessary to judge results properly.

Afternoon Session: Symposium *on Flat-Foot*

The most important consideration today in treating flat-foot, as in the case of Perthes disease, is knowledge of its etiology and pathogenesis. Treatment, generally outlined, was conservative. Some authors preferred arthrodesis. It was emphasized that great care must be exercised in selecting cases for surgery.

Tuesday, January 17

Morning Session: Fractures *of the Forearm*

The consensus was as follows: fracture of the forearm in children is a distinct clinical entity and the opinion was unanimous that:

1. The treatment of choice for these fractures in children is closed manipulation and plaster fixation;

2. The correction of rotation need not be as perfect as that in the adult, as growth has a modeling and corrective action;

3. Indications for surgical correction are exceptional.

In the adult there was agreement that: (1) fracture of both bones of the forearm with displacement is an indication for surgical correction; (2) the most used procedure to date is intramedullary fixation with Kirschner wire followed by the application of a cast. Emphasis was placed on the importance of correction of rotation. J. L. Bado (Uruguay) presented a well illustrated paper on the value of x-ray study of the location of the bicipital tuberosity (tuberosity view) to determine the degree of rotation of the proximal fragment, together with the study of the relationship of the ulnar styloid to the distal end of the radius to measure the degree of rotation of the distal portion.

For the Monteggia fractures closed reduction usually gives good results, but when reduction of the dislocated radius is carried out without successful reduction of the ulnar fracture, open reduction with intramedullary nailing is done.

Afternoon Session

Eight papers were presented in each of three sectional meetings by authors selected by the Local Committees of the Sociedad Latino Americana de Ortopedia y Traumatología in each country. Thirty minutes was devoted to discussion.

Wednesday, January 18

The morning session was devoted to conferences and visits to the scientific and commercial exhibits.

Afternoon Session: Symposium on Traumatic Lesions of the Distal End of the Femur and Proximal End of the Tibia, Including Lesions of the Cartilage.

The classification of these fractures was discussed and the functional results with relation to the patellar articulation, early and late, were reported in different types of fractures. Emphasis was placed on the good results which could be obtained with conservative measures. The indications for surgery were well set forth.

The remainder of the Congress was devoted to conferences and selected papers.

The papers presented at this Latin American Congress were of high quality, recording accurate clinical observations, clinical statistical studies, and sound scientific investigations as well as improved techniques.

Among the distinguished guests who came from countries out of Latin America were: from Belgium, Dr. Octavio Coquelet: from Canada, Dr. Calixte Favreau and Dr. Edouard Samson; from England, Dr. J. Trueta; from France, Dr. Paul Padovani; from Germany, Dr. Herbert Gardemin, Dr. Max Lange, and Dr. F. Loeffler; from Spain, Dr. Manuel Bastos Ansart, Dr. Antonio Hernández Ros Codorniú and other delegates; and from the United States, Dr. Harold B. Boyd, Dr. Guy A. Caldwell, Dr. James Callahan, Dr. Alan DeForest Smith, Dr. Fred Ferciot, Dr. Alfred Gallant, Dr. Ralph K. Ghormley, Dr. Beckett Howorth, Dr. Earl D. McBride, Dr. Ignacio Ponseti, Dr. Joseph Risser, Dr. Arthur Steindler, and many others.

The Congress came to a close with a formal Banquet held in the Grand Ballroom of Chandeliers in the Hotel Del Prado, where it was announced that the next Congress will take place in the city of Caracas, in January 1959, under the Presidency of Dr. Juan Colmenares. Dr. Oscar Maróttoli, from Rosario, Argentina, was inaugurated as the next President of the Sociedad Latino Americana de Ortopedia y Traumatología for the period running from 1956 to 1962.

News Notes

The next Annual Meeting of **The American Orthopaedic Association** will be held at The Homestead, Hot Springs, Virginia, June 24 to June 27, 1957.

The next Annual Meeting of the **Western Orthopaedic Association** will be held in Phoenix, Arizona, from October 30 to November 3, 1956, under the presidency of Dr. James Lytton-Smith.

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in Chicago, Illinois, January 26 to 31, 1957.

AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Final date for filing applications for the Part II Examinations to be given in January 1957, in Chicago, is August 15, 1956. Application should be made to the Secretary, Dr. Sam W. Banks, 116 South Michigan Avenue, Chicago 3, Illinois.

EXCHANGE FELLOWSHIPS

The Exchange Fellowships Committee of The American Orthopaedic Association invites application from American orthopaedic surgeons for the four fellowships to visit Great Britain in the spring of 1957. All applications must be in the hands of the Committee by December 1, 1956; any submitted after that date cannot be considered. General requirements for each applicant are:

1. American citizenship;
2. Successful completion of Part II of the American Board of Orthopaedic Surgery Examinations;
3. The applicant must be under forty years of age as of December 1, 1956.

Application forms and other details of application will be furnished upon written request to the Committee Chairman, Dr. J. Neill Garber, 806 Hume Mansur Building, Indianapolis 4, Indiana.

KAPPA DELTA AWARD

The Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons announces that all manuscripts which are to be entered for the Kappa Delta Award, which is presented annually for the outstanding scientific contribution in the field of orthopaedic surgery, should be forwarded to the Chairman of the Committee, Dr. Donald B. Slocum, 132 East Broadway, Eugene, Oregon. Since the winner of the Kappa Delta Award will present his paper before the General Membership of the Academy at the Annual Meeting in January 1957, it is necessary that all manuscripts be received by August 15 so that they may be properly evaluated and forwarded to the Executive Committee of the Academy for approval. This is a departure from previous years when final selection was not made until October 1.

The National Society for Crippled Children and Adults will hold its annual convention October 28 to 31, 1956, in Washington, D. C. Dr. Walter Blount, immediate Past-President of The American Academy of Orthopaedic Surgeons, is among the principal speakers scheduled for the general sessions planned for the mornings of the convention. Dr. James B. Johnson, Newark, Ohio, is Chairman of the 1956 Convention.

THE GERMAN ORTHOPAEDIC ASSOCIATION

Hamburg, September 14, 1955

The Forty-third Congress of the German Orthopaedic Association was held in Hamburg, on September 14, 1955. The following symposia were presented: 1. The Biology of Bone and Cartilage, 2. The Disabled Hand, 3. Timely Problems of Vertebral Pathology.

Among members presenting papers, Pauwels of Aachen, spoke on the significance of functional anatomy in orthopaedics as exemplified by the hip joint. He showed the practical application of the laws of physics to the solution of problems in orthopaedics. There were noteworthy contributions by von Voss of Lubeck on transient coxitis and Imhauser of Dortmund on a new method for operative treatment of osteo-arthritis of the hip with the aid of temporary resection of the trochanter by the method of Brandes.

The Congress, presided over by Professor Dr. C. Mau of Hamburg, was attended by more than 500.

ANNOUNCEMENT BY THE ORTHOPAEDIC RESEARCH AND EDUCATION FOUNDATION OF THE FIRST RESEARCH AWARDS

May 21, 1956

At the last meeting of the Board of Trustees of the Orthopaedic Research and Education Foundation a review was made of the questionnaires on orthopaedic research from the 1955 survey. Sixteen of the most promising projects were selected from these questionnaires representing research which the Foundation might be in a financial position to support at this time. A request was then sent to each investigator to submit a formal application for consideration of a research grant if he so wished. Eleven formal applications were received. Four of these have now been approved by the Board for grants totalling $6,800, and are as follows:

1. Investigator: Jonathen Cohen, M.D. Work to be done at the Children's Medical Center, Boston, Massachusetts.

Title of Project: Three Dimensional Anatomy of Haversian Systems in Bone.

2. Investigators: William N. Harsha, M.D., and Samuel Moore, M.D. Work to be done at the University of Oklahoma School of Medicine, Oklahoma City, Oklahoma.

Title of Project: A Study of Distracting Forces Imposed upon Normal Long Bones and Long Bones Subject to Physiological Decalcification.

3. Investigators: George O. Rose, M.D., and Thomas O. Shindler, M.D. Work to be done at the Texas Medical Center, Houston, Texas.

Title of Project: Compression Studies on Bone in Tissue Culture.

4. Investigator: John O. Esslinger, M.D., Birmingham, Michigan.

Title of Project: Intramedullary Implant for the Attachment of an External Prosthesis.

The Tenth **Inter-American Congress of the Pan American Medical Association** will be held in Mexico City, March 25–31, 1957. The President of the Association is Dr. Pedro A. Gutierrez Alfaro, Minister of Sanitation and Public Welfare of Venezuela; the executive Director is Dr. Joseph J. Eller, 745 Fifth Avenue, New York, N. Y.

The Third Annual Meeting of the **Mid-Central States Orthopedic Society** was held in Oklahoma City, April 20 and 21, 1956, under the Presidency of Dr. Elias Margo. The following program was presented:

April 20, 1956

Two Cases of Severely Comminuted Fractures of the Forearm. Dr. Frank Stuart.
Car Window Fractures. Dr. Howard Shorbe.
Postoperative Spine Fusion Technique. Dr. Port Johnson.
Fractures of the Femur. Dr. W. K. West.
One Case of Arteriovenous Aneurysm Involving Bone. Dr. Richard Burgtorf.
Rotator Cuff Injuries. Two Cases with Special Problems of Management. Dr. Richard Burgtorf.
Epiphyseal Stimulation. Dr. Don H. O'Donoghue.
Fractures of the Talus. Dr. Marvin K. Margo.
Treatment of Acromioclavicular Separation and Fractures of the End of the Clavicle. Dr. Charles Graybill.
Phalanged Stabilized Acetabular Cup—Otto Pelvis. Dr. Earl D. McBride.
Fractures of the Femoral and Tibial Condyles with Open Reduction. Dr. Robert Holt.
Extensile Exposure in the Hand. Dr. William L. Waldrop.
Case of Non-Union of Fractured Clavicle in a Child. Dr. William Miller.

April 21, 1956

Muscular Dystrophy. Lesion of the Hip. Dr. Sam Moore.
Bunions. Dr. Elias Margo.
Severe Fractures of the Pelvis. Dr. S. F. Tompkins.
Use of Bone Grafts in Femoral Neck Fractures. Dr. Russell D. Harris.

The following officers were elected to serve during the year 1956 to 1957:
President: Dr. J. Sims Norman, Pueblo, Colorado;
Vice-President: Dr. F. Walter Carruthers, Little Rock, Arkansas;
Secretary-Treasurer: Dr. H. O. Marsh, Wichita, Kansas.

The Fourth Annual Meeting will be held at the Broadmoor Hotel, Colorado Springs, Colorado, March 29 and 30, 1957.

Book Reviews

Fractures of the Facial Skeleton. N. L. Rowe and H. C. Killey. Baltimore, The Williams and Wilkins Co., 1955. $22.00.

Our British colleagues have presented in "Fractures of the Facial Skeleton" an encyclopedic text encompassing the many problems of trauma to the face. The volume includes chapters on etiology, surgical anatomy, clinical and roentgenographic examination, diagnosis, treatment, and preoperative and postoperative care of all types of fractures. In addition, there are sections on war wounds, anaesthesia, bone growth and healing, associated head and eye injuries, and reparative surgery of the face. The concluding chapter is uniquely interesting; it is titled "The Historical Background of the Treatment of Maxillo-Facial Injuries" and is composed of excerpts of surgical writings from the pre-Christian era to the present. Of interest also is the account in Chapter 15 of the organization of maxillo-facial units and special centers during World War II. The closely coordinated teamwork of specialists in several related fields, established in these centers, continues today at Rooksdown House in Basingstoke where the authors are consultants in oral surgery. Other contributors to this volume are also associated with Rooksdown House in a consulting capacity.

The authors have succeeded in maintaining a balance between the surgical and dental approaches to facial injuries, and have omitted none of the most advanced techniques in both fields. It is only natural that in their striving for completeness the authors are guilty of unnecessarily detailed descriptions of the dental approach to mandibular fractures. The trend among American surgeons is away from cast metal cap splints, intra-oral saddles, extra-oral skeletal pins (Stader), and complex wiring techniques. This trend has progressed despite the fact that V. H. Kazanjian, of Boston, was one of the leaders in reviving and perfecting many of these methods while an officer with the British forces in France, during World War I. It may be that the American surgeons are impatient and want to get the job done once and for all, without the aid of cumbersome appliances or the daily adjustment of splints. Whatever method is chosen, however, prompt reduction of the fracture, definitive fixation of the fragments, and adequate maintenance of normal occlusion until healing is complete always remain the surgeon's objective.

This book should prove a useful reference book to those concerned with facial injuries. It is very complete, well illustrated, and quite readable. Throughout the book the authors have used drawings and photographs to clarify the descriptions of methods and techniques in the text. A carefully arranged and exhaustive index makes reference easy. The chapter references and general bibliography add to the value of the book.

It seems appropriate that the foreword to this valuable contribution to the literature should be written by Sir Reginald Watson-Jones, whose *Fractures and Joint Injuries* is so revered by American surgeons.

Bradford Cannon, M.D.

Doctor and the Patient and the Law. Ed. 3. Louis J. Regan, M.D., LL.B. St. Louis, The C. V. Mosby Company, 1956. $12.50.

The increasing need of the physician to be alert to his legal responsibilities and liabilities and his need for a ready reference book on the subject is well stated in the preface to this volume. "The likelihood of being sued for malpractice is now so great that it constitutes a definite occupational hazard to the practicing physician or dentist; and an increasing number of negligence actions are being brought against nurses and hospitals. Particularly during the last quarter-century there has been a tremendous increase in the number of unjustifiable malpractice suits."

About two-thirds of this volume is a casebook, each topic prefaced by a general explanation. Cases cited are given with exemplary brevity and a minimum of legal language. The remaining third, perhaps even more valuable, contains specific, detailed, simple information on how to keep out of medico-legal trouble and how best to provide protection against the misguided or the unscrupulous.

Much of the material in the previous editions has been rewritten and enlarged for this edition. New sections have been added on, "Public Health Law", "Foeticide, Infanticide, Concealment of Birth or Death", "The Grievance Committee and Malpractice", and "The Patient's Interest in Malpractice".

J. A. R.

The Shoulder and Its Environs. James C. Bateman. St. Louis, The C. V. Mosby Co., 1955. $16.25.

This 565-page book is the fruit of a commendable and successful attempt to present a complicated subject, cutting across numerous specialties, in a way that will be useful to all clinicians. The many causes of pain in and about the shoulder are segregated according to three broad symptom patterns — shoulder pain predominating, shoulder and neck pain, and shoulder plus radiating pain. The potential of various lesions for the production or accentuation of pain is considered separately in relation to these presenting

patterns. The organization of material is well conceived, and represents a sound clinical approach to the problem of shoulder pain. The text has a refreshing absence of the narrow and specialized horizon so common in monographs, and if there is considerable repetition throughout the sections of the book, the material discussed makes this repetition necessary.

Pre-clinical chapters on embryology, anatomy, and physiology are concise, well rationalized, and faithfully integrated with the practical clinical problems which follow. The profusely illustrated chapter on clinical examination is excellent. It is disappointing to find in the chapter on fractures and dislocations only eight lines of text devoted to injuries of the cervical spine and their peripheral sequelae. Neurological—excepting spinal cord—vasomotor, and neoplastic lesions are well described, but little or nothing is said about infection. The final chapter, which deals with management and assessment of disability, will doubtless prove useful to surgeons practicing in the Province of Ontario, but is unlikely to arouse more than a mild interest in surgeons in other areas.

The profusion of excellent illustrations at times approaches the superfluous. Clinical material is presented in a dogmatic fashion, and many of the opinions expressed do not conform to established clinical thought. It is distressing to read that spontaneous subsidence of acute symptoms from a painful calcific deposit is rare; that unrepaired cuff tears eventually result in frozen shoulders; that a recurrent dislocation in which the humeral head displaces into an enlarged subscapularis recess originated in a primary dislocation occuring through a weak spot in the inferior capsule; and that a "whiplash" lesion is nothing more than a sudden flexion injury which tears the ligamentum nuchae or fractures the spinous process of the seventh cervical vertebra. These personal opinions, to which the author has every right, would be more digestible to the reader if designated as such.

It seems certain that the frequency with which the problem of shoulder pain and its concomitants is encountered in most branches of medicine will make this book a valuable and welcome addition to the working libraries of all clinicians. It contains more useful information concerning this complicated region than any other text since Codman's classic publication.

Harrison L. McLaughlin, M.D.

LEHRBUCH DER PRAKTISCHEN ORTHOPÄDIE. Dozent Dr. Walther Aberle, Professor Dr. Philipp Erlacher, Dr. Alexander Hartwich, Dr. Alfons Königswieser, and Professor Dr. Oskar Stracker. Edited by Professor Dr. Philipp Erlacher. Wien, Wilhelm Maudrich, 1955.

This textbook is unusual in two respects: first, it has been written by five orthopaedic surgeons, all of whom were pupils of Professor Hans Spitzy of Vienna, with the avowed purpose of presenting the opinions and methods of their revered teacher; second, because it presents orthopaedic surgery according to the age of the patient; that is, from birth to the twelfth year; from the twelfth to the twentieth year; then the adult period; finally, old age. A fifth chapter deals with amputations and prostheses. This division of the subject is justified, according to the authors, by the different reactions of the varying age groups to the same etiological factors. Although written by different authorities, unity can be claimed for the volume since all five authors were trained in the same school and according to the same fundamental principles.

In the introduction, Dr. Erlacher gives an historical summary of the development of orthopaedic surgery. According to him, the sphere of modern orthopaedic surgery includes the study, prevention, and treatment not only of congenital and acquired deformities, but also of the chronic diseases of the motor apparatus. At the turn of the century orthopaedic surgery was concerned chiefly with congenital deformities, rickets, tuberculosis and paralytic conditions. During the first decade of the twentieth century there was a marked increase in the number of deformities due to static abnormalities. Then with the first world war came a huge increase in traumatic cases and in amputations. There was a corresponding upward surge in the development of prostheses. As war injuries gradually disappeared from the scene their place was taken by an ever-increasing number of industrial and traffic accidents. Though the rachitic deformities disappeared as the result of scientific prevention, the arthritides increased, particularly after World War II. More recently there has been a striking increase in what the authors term "the lumbar-sciatic complex".

Corresponding to this unusually large, complex group of orthopaedic cases there have been in the past—so say the authors—two groups of orthopaedists: those primarily interested in congenital anomalies and diseases of children, and those particularly skilled in the traumatic cases of adult life and in the diseases of bones and joints. This fact furnishes another justification for the divison of the present text book into chapters dealing with various age groups.

Although this reviewer would like to accord his wholehearted approval to this volume, he is compelled to admit certain shortcomings which seem to be inherent in the methodology. The demarcation line between orthopaedic diseases of infancy, childhood, adolescence, and "the teens" is not sharp. Perthes disease and slipped epiphysis begin in childhood but extend into adolescence; all club-feet are not cured during childhood; infantile paralysis frequently strikes the adult; Still's disease leads to the arthritis of adult life; scoliosis may begin at any age. Consequently, the division of the book into chapters according to age groups is bound to result in repetition and to the expression of varying opinions, depending upon the author. The work therefore

lacks the strength which is a result of single authorship. To the trained orthopaedic surgeon this variety of opinion probably adds to the interest; to the immature student, for whom the work is chiefly intended, it may represent a source of confusion. This possible shortcoming does not detract from the high standard of excellence of the individual chapters, particularly the first one which is written by Professor Erlacher, and deals with the orthopaedic surgery of childhood.

The book is dedicated by the authors to their teacher, one of the world's masters of orthopaedic surgery.

Leo Mayer, M.D.

PROCEEDINGS OF THE INSTITUTE ON REHABILITATION CENTERS. Chicago, National Society for Crippled Children and Adults, Inc., 1955. $1.60.

This seventy-two page brochure is a compilation of papers presented at the first Institute of Rehabilitation Centers, held in Chicago in June 1954. It constitutes an authoritative "how-to" manual for all workers in the field of rehabilitation. It gives advice on determining the need for a center, or establishing relationships with all the various groups interested in rehabilitation, and on assigning team responsibilities. It also discusses the agencies, public and private, that contribute to the support of centers, and the problems of fund raising and financing. Copies of this manual may be obtained from the National Society, at 11 South LaSalle Street, Chicago 3, Illinois.

J. A. R.

THE SPINE. A RADIOLOGICAL TEXT AND ATLAS. Bernard S. Epstein, M.D. Philadelphia, Lea and Febiger, 1955. $16.50.

This is an extensive review of the normal and abnormal roentgenographic appearance of the spine. Congenital malformations are discussed thoroughly, as are the effects upon the spine of endocrine and metabolic disturbances, inflammatory disease, neoplasms, and trauma. The chapters on disease of the intervertebral discs and on the contents of the spinal canal are excellent.

It is obvious that the author is very familiar with the literature. In the opinion of the reviewer, however, the extensive detailed and enumerative quotations from the literature disturb the continuity of the text. A more condensed use of the publications of others would make for easier reading, and at the same time would bring the author's personal experience and critical evaluation more into the foreground.

Numerous illustrations are included. Most of them are excellent. In others, the disease process could be demonstrated to better advantage by restricting the illustration to the actual region of abnormality.

This is, to the knowledge of the reviewer, the most extensive publication on the subject in the English literature and should be of great value to anyone who is interested in the spine.

Richard Schatzki, M.D.

BONE AND JOINT X-RAY DIAGNOSIS. Max Ritvo, M.D. Philadelphia, Lea and Febiger, 1955. $20.00.

Max Ritvo's new volume, *Bone and Joint X-Ray Diagnosis*, is a thorough compilation of the literature, but lacks synthesis by the author. It is intended primarily for the roentgenologist, but is so thorough and complete a compendium that the orthopaedist and general clinician will find it of value as a review of the literature. The reader, however, will have to supply his own critique.

The English used is clear and bereft of padding. The statements concern facts gleaned from the literature and a clinical, as well as roentgenographic, description of the entity is made. In discussing "Condensing Osteitis of the Ilium", for example, there is, in addition to the introductory paragraphs, a description of pathological findings, symptoms, physical examination, roentgen findings, and differential diagnosis. This is a general pattern throughout the book. In point of fact this results in a full-bodied picture of the disease with heavy emphasis on the roentgen findings. It is of greater value for the trained physician than for the student since it is a mass of carefully assembled, rather than digested material.

Unfortunately, every entity is not illustrated. This lack could bother readers who are unfamiliar with the lesion and wish to visualize it. Since the volume is more likely to be used for reference than a text, this lack may also be felt by the hurried physician seeking to conjure an analog to his own clinical problem. With the physician's own case clear in his mind, however, the lack of illustration beautifully dresses his specific skeleton.

The reproduction of roentgenograms is clear, and the common fault of attempting to include too much of the skeleton in one picture is generally avoided. The soft tissues so important in skeletal diagnosis by roentgenogram are poorly shown, but good visualization of these structures awaits an advanced technology that has generally eluded our civilization.

The weakness of this volume appears to consist in a failure to emphasize the important, or to offer it in a manner that makes it intelligible or embeds it firmly in the reader's mind. The paragraphs are long and in many instances not synthesized and organized, as in the discussion of Sudeck's Atrophy. In trying to be complete the author may be forced out into unfamiliar water where he must clasp the driftwood floating by to keep from sinking—some of which has poor floatation.

In complimenting this volume, its completeness and culling of the literature stand out. It is not recom-

mended as a first reader for the student, enabling him to understand the basic trends running like an underground stream through various classes of lesions. As a complete reference, it will be of great value to the practicing roentgenologist and orthopaedist who have an occasional chance to peruse its pages. Following the perusal however, the reader will have to evaluate for himself just how firm was the ground on which the author stood when he made his statement.

Albert B. Ferguson, Jr., M.D.

Chirurgische Operationslehre. Herausgegben von Professor Dr. Burghard Breitner. Wien, Urban und Schwarzenberg, Verlag, 1955. Band I, DM162, Band II, DM148.

These two large volumes form a textbook on surgical techniques, which is intended for expansion. The volumes are loose-leaf in binding with a generous capacity for additional pages of notes and clippings. Under the general editorship of Prof. Dr. Breitner, Director of the Department of Surgery at the University of Innsbruck, each section has been written by a specialist. There is an extensive bibliography for each section but, unfortunately, there is no index, although the table of contents, which is given in great detail, partially makes up for this lack. The volumes are profusely illustrated. There are 1,643 illustrations; the great majority of these are artists' drawings. There are many diagrams, a few roentgenograms, and photographs which are chiefly of instruments or equipment.

The work starts with two sections on general operating-room techniques and a section on anaesthesia. There is a long section (306 pages) on brain surgery, and shorter sections on surgery of the spine and of the sympathetic nervous system. Of two sections on oral surgery, one is devoted almost wholly to the repair of defects of the upper jaw and upper lip. There are two sections on plastic surgery, a section each on surgery of the throat, breast, lungs, pulmonary tuberculosis and a general section on abdominal surgery.

This is not a work to be urged upon a surgical specialist. However, one can whole-heartedly recommend that it is well worth examining on the next visit to the library.

J. A. R.

Surgery of the Ambulatory Patient. Ed. 3. L. Kracer Ferguson, M.D., F.A.C.S. With a Section on Fractures by Louis Kaplan, M.D., F.A.C.S. Philadelphia, J. B. Lippincott Company, 1955. $12.00.

Dr. Ferguson's experiences as Chief of the Surgical Out-Patient Department, University of Pennsylvania Hospital, from 1928 through 1942 were collected in the first edition of his popular text. A revision appeared in 1946 bringing it up to date by including techniques in the use of antibiotics. Now a third edition presents the comprehensive material in contemporary terms. The book consists of three main sections which encompass twenty-nine chapters. Co-authors contribute chapters on anaesthesia, infection, genito-urology, and fractures.

Section I covers Surgical Principles and Lesions. These fundamentals are thoroughly and concisely reviewed. An addendum came to the reviewer's mind while reading about the toxicity of local anaesthetic agents and the freedom with which procaine-epinephrine infiltration techniques are used. Several years ago, during treatment of an accident case in an out-patient department, a bottle containing ten cubic centimeters of 0.1 per cent of epinephrine hydrochloride was emptied into a watch glass and then infiltrated into a patient's back under the impression that it was epinephrine-procaine 1 to 200,000 solution. A severe vasopressor reaction occurred which fortunately an alert anaesthetist recognized and quickly neutralized with local cyclaine infiltration, intravenous procaine and intravenous Benodaine hydrochloride drip.

Section II is devoted to Regional Surgery, and this covers conditions of the caput, corpus, and cauda completely. The author includes excision of thyroglossal cyst, coccygectomy, wiring of ruptured costochondral cartilage, and resection of scalenus anticus under local anaesthesia, as examples of ambulatory surgery, and lists Freiberg's disease and Koehler's disease as though they were synonyms for osteochondritis of the second metatarsal head. True limb-length measurement from the anterior superior iliac spine to the floor is not generally considered as reliable a measurement as to the medial malleolus. I agree with the author that the relative height of the iliac crest is adequate mensuration for clinical purposes. However, the simple method described by Goldberg (American Journal of Surgery, 68: 89–90, 1945) has always impressed me as the best way to aspirate a knee joint, and in my opinion, it seems easier to aspirate at the upper, inner pole of the patella than more laterally, as Dr. Ferguson suggests.

Section III deals with the musculo-skeletal system and stresses those conditions which can be handled in the office. I disagree with the preference for local anaesthesia injected into a hematoma at the fracture site. While this enables the surgeon to obtain reduction in a procedure in his office, it certainly permits much less relaxation than a block or general anaesthic and it increases the risk for both patient and physician. Personally, I am unfriendly to the use of the fluoroscope in fracture therapy and to wedging in plaster, and it seems to me that compression fractures of the thoracic and lumbar spine, without displacement, do not need plaster jackets in hyperextension. However, these are merely personal opinions. My only other suggestion about this section would be that the chapter on fractures of both bones of the forearm and on dislocations of the radius at the elbow with fracture of the ulna be revised in the light of Evans' contribution

to the literature on the effect of rotation in the mechanism and treatment of forearm injuries. (*The Journal of Bone and Joint Surgery*, 33-B, 548–561, Nov. 1955).

Dr. Ferguson states that the purpose of this book is to provide information for treatment so that the ambulatory patient can be taken care of in the out-patient department of the hospital or in the surgeon's office. I think that he has succeeded admirably, and I hope that the future usefulness of the book will be enlarged by periodic revision.

Thomas F. Broderick, M.D.

Hand Surgery in World War II. Edited by Sterling Bunnell, M.D. Washington, Office the Surgeon General, Department of the Army, 1955. $3.75.

This book is a review of the experience of the Medical Department of the United States Army in the treatment of hand injuries during World War II, and it also covers briefly the organizational and the clinical aspects of the subject. It is interesting to note that a report of hand injuries in the first world war comprised not quite 300 lines, whereas this volume, consisting of 419 pages, leaves the reader with the impression that certain aspects of the problem have received but scant attention.

The book includes nineteen chapters by eighteen authors. The introductory chapter is concerned with the initial phases of the organization of special Sections for Hand Surgery in the Zone of the Interior. A chapter by Dr. Sterling Bunnell, Civilian Consultant for Hand Surgery to the Secretary of War, summarizes the knowledge gained during the Second World War; other chapters are concerned with the treatment of hand injuries received in the Mediterranean and the European theaters; one chapter describes hand wounds of patients received in a debarkation hospital, and nine chapters summarize the experiences of the nine special Sections for Hand Surgery which were finally set up within the Zone of the Interior.

This is a very worth-while book. It is the successful result of a major effort to collect and record in a readily available and easily read form the lessons learned during World War II. The account of the steady progress made in the care of combat-injured hands tells the story of the growth of our knowledge, and stresses the value of a book such as this, should we find ourselves in a similar situation in the future.

From the clinical point of view, there are few statistics or end-result studies. Rather general comments are made concerning splinting, skin replacements, nerve repair, bone grafting, immobilization of joint, tendon replacement, amputations, transposition of digits, and rehabilitation procedures. The authors discussing these topics have dealt with them in their own fashion, each narrating his own experiences and findings rather informally. Careful analysis of their material and end-result studies would, of course, have been virtually impossible.

The order of presentation may be criticized. The summary and conclusions as embodied in Dr. Bunnell's chapter in the early part of the book is followed by the reports from the nine separate Hand Centers, which may be confusing to some readers. A concluding chapter with editorial comment on the material presented from the surgical history of the nine Centers would have been satisfying and valuable.

The illustrations are black and white; many of them are reproductions of roentgenograms and photographs made under war conditions and, therefore, are of inferior quality. The medical artists of the Armed Forces Institute of Pathology have done a creditable job of retouching these and making them intelligible.

This is a valuable book which will be of interest to all who are concerned with the surgery and the reconstruction of the hand.

Thornton Brown, M.D.

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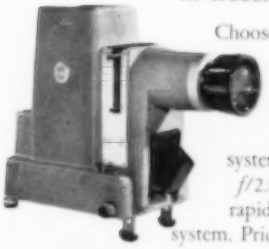

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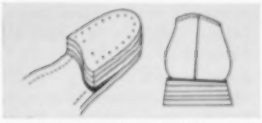

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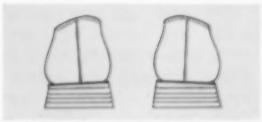

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Top-Grade Waterproofed Leather Soles

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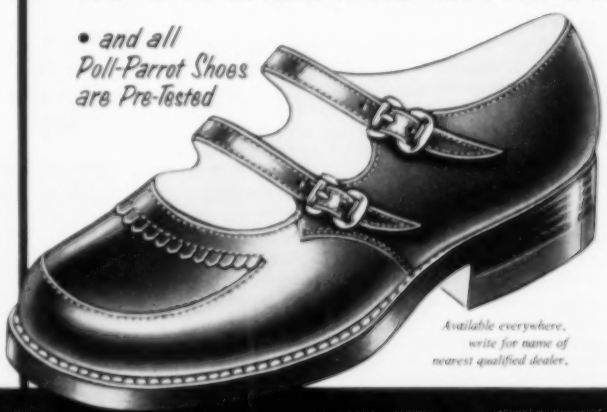
When you say "*Poll-Parrot Guide-Rite*", here's what you're recommending: Shoes that are made by people who know children's *feet* as well as shoes. Shoes that are developed by pedic *specialists*, are made on the finest-fitting lasts anywhere. Are quality built, quality controlled, every step of the way. And are Pre-Tested by real boys and girls. For, into each pair go all the experience, resources, skill . . . *and vast research facilities* . . . of the *world's largest* shoemaker! And, when prescribing Orthopedic adjustments, specify Poll-Parrot Guide-Rites with the famous Tru-Guide features shown at left.

• *and all Poll-Parrot Shoes are Pre-Tested*



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"Just what the Doctor ordered"

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Division of International Shoe Company, St. Louis 3, Mo. Makers of Poll-Parrot and Scamperoo Shoes for children; Rand and Randcraft Shoes for men and boys; Trim Tred and Helter Skelter Shoes for women; Star Brand and Hy-Test Work Shoes; and Official Boy Scout and Girl Scout Shoes.

Mr. Louis C. Weld, President of G. W. Chesbrough Co., showing the new Cosyfoot surgical shoe with a Denis Browne splint.

Straight last, rigid sole prevents buckling or warping.

Firm counter holds heel gently, without slipping or undue pressure.

"here's a surgical pre-walker your patients can afford to buy"

"It's usually a problem and a hardship for parents to meet the expense of corrective shoes.

"This was brought home to me very clearly when one of my daughter's children needed a surgical shoe. I was amazed at the high price she had to pay . . . and decided to do something about it.

"We put all 57 years of our shoe-making experience into designing a brand-new surgical shoe without sacrificing quality. Your patient can afford to buy it and it is available to them at a low price. We can offer parents a real *help*—and make those parents your friends for years to come.

"Let me tell you about the new *Cosyfoot* surgical. It's designed for use with or without Denis Browne or night splints. It's a prewalker on a straight last. The open toe allows for normal growth. You can see toes are correctly aligned. You can make sure the heel is set fully down in the shoe.

"Notice the toe area is as wide as the ball measurement. This allows the foot to grow straight, without pressure from inner or outer edge. *This shoe is made to hold its shape.*

Write for a desk sample of these moderately priced surgicals. Examine them at our expense. Send us your name and address and I will send you a sample by return mail."

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TELFA Strip is ideal for minor wounds, burns and plastic cases. Easy to apply. Doesn't hurt or tear the scab when you take it off. Convenient sizes—and they can be cut to fit any wound, without raveling.

Note easy and painless removal of TELFA dressing on 6th day after excision of neck tumor. The healing tissue and stitches are undisturbed, no sign of irritation. Wound is dry and healing is well advanced.

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Now you can dress any wound with TELFA—wounds that you have heretofore dressed with gauze, or with sponges and pads.

TELFA is now available in two forms: TELFA Non-Adherent *Strips*, for simple, minor wounds and the new TELFA Non-Adherent *Sponge-Pads* for all routine surgical wounds and even for drainage cases.

This means that you can now employ the advanced TELFA *technique throughout your dressings practice. And save up to 41% on dressings costs.*

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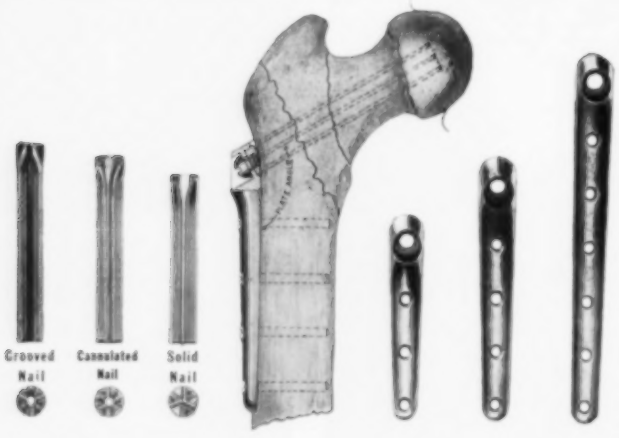
for

Treatment of Fractures of the Femur and Trochanter



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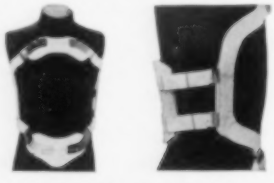
Effective 3-POINT Hyperextension and Flexion Braces



Simple strap-hook adjustment. Easy on, easy off. Plastic tube covering sides adds to patient comfort, prevents irritation in breast-axilla and groin areas.

HYPEREXTENSION BRACE—Efficient, comfortable hyperextension is provided in cases of traumatic or pathological compression fractures of the lower thoracic and lumbar spine.

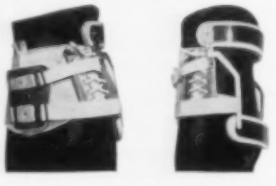
★ Luxuriously padded with super-soft ½" vinyl sponge. Non-toxic, washable. Note cut-outs at sternal notch and groin for added patient comfort. Lateral pressures on torso and iliac crests are completely eliminated by novel shaping and reinforcing of side bars.

Price $45.00

FLEXION BRACE—3 point pressure assures flexion in lumbar spine. The most effective unit available against disk syndromes and spondylolisthesis. Firm abdominal pad for positive counter-pressure in abdominal area. Cool elastic front. Same soft padding as above.

★ ***New Price $40.00***

Available in fully leather lined model at $47.50



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Note lacing adjustment at sides. Elastic tongue under laces adds to patient comfort.

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Part No. 140

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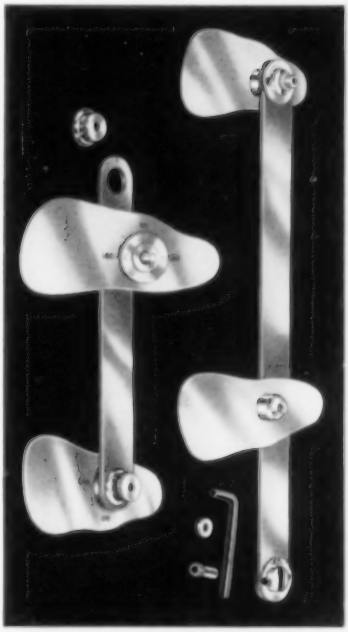
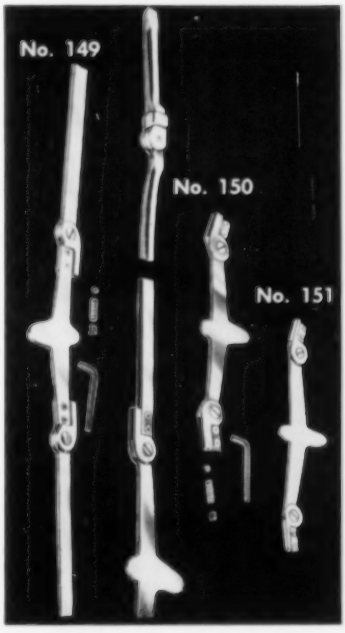
Free Ankle Joint with 90 degree stop, designed for use with long leg braces. Plain or plated finish. Manufactured from forged steel.





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for HYPEREXTENSION OF THE SPINE

COMPRESSION FRACTURES and other cases requiring positive hyperextension such as Osteoporosis with Kyphosis, Adolescent Epiphysitis and Marie Struempell's Spondylitis.

Rigidly performs function of body hyperextension cast; locked on patient when adjusted to proper hyperextension; not removed for bathing or sleeping; adjustable to physical changes, light, clean, sanitary, durable, conducive to physiotherapy and return to light duties.

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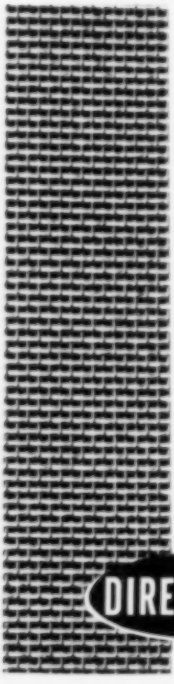

Drop-foot Brace or Night Splint

with the new DIREKT-FORM

Double-thickness of medium D-F mesh, with center layer of burlap. 2 coats dipped D-F hardener; added finishing coats brushed on. Edges sanded, finished and protected by elastic tape—then completely waterproofed and sealed by D-F hardener.

DIREKT-FORM aluminum-alloy wire and woven fiber mesh is a new, patented material. The mesh is easily formed directly to the body of the patient. This molded form is then dipped into the plastic hardener. Also, the DIREKT-FORM method has a unique advantage over plaster. A special softener is supplied which permits reshaping or adjustment of a semifinished or finished DIREKT-FORM device.

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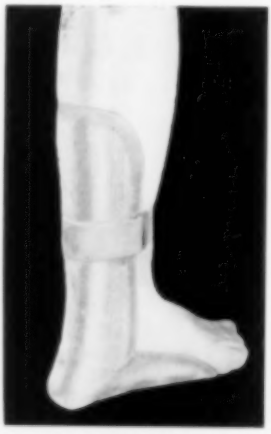

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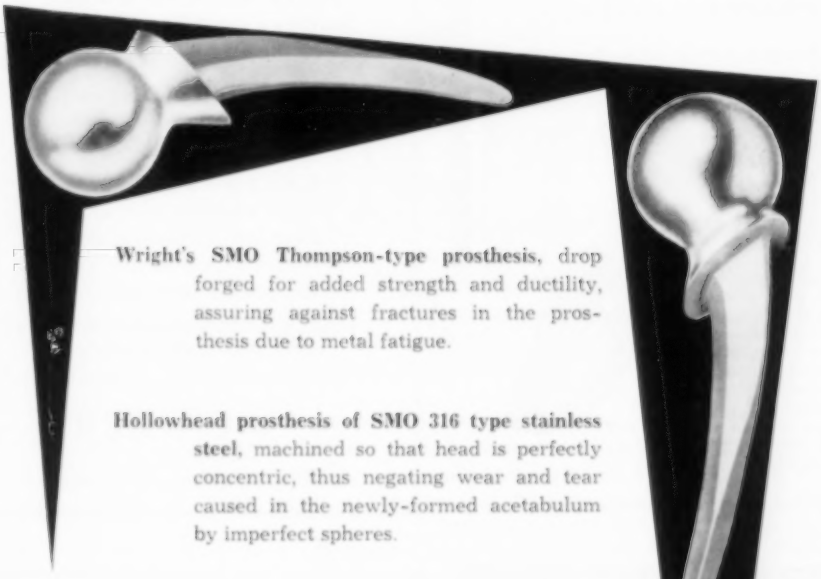
SMo Stainless Steel Drop Forged HOLLOW-HEAD HIP PROSTHESIS



Wright's SMO Thompson-type prosthesis, drop forged for added strength and ductility, assuring against fractures in the prosthesis due to metal fatigue.

Hollowhead prosthesis of SMO 316 type stainless steel, machined so that head is perfectly concentric, thus negating wear and tear caused in the newly-formed acetabulum by imperfect spheres.

It has taken two years of engineering and research to develop this first drop forged, hollow-head prosthesis. This newly-developed prosthesis is 100% SMO type 316 stainless steel. Drop forged in one piece, there is no catalyst or foreign metal used in its manufacture. This prosthesis has been laboratory-tested and mechanically-proven.

HEAD SIZES: 1⅝, 1¾ and 1⅞ inches
SHAFT LENGTH: 5½ inches
PRICE: $55.00

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Clarks back this promise with 131 years of shoe craftsmanship. They *keep* it by making children's shoes which are based on the natural shape of a child's foot . . . made in different widths to each length size . . . fitted with scientific accuracy on a special Footgauge for *length*, for *breadth* and for *girth*. That's why so many children in over 60 countries in the world wear Clarks.

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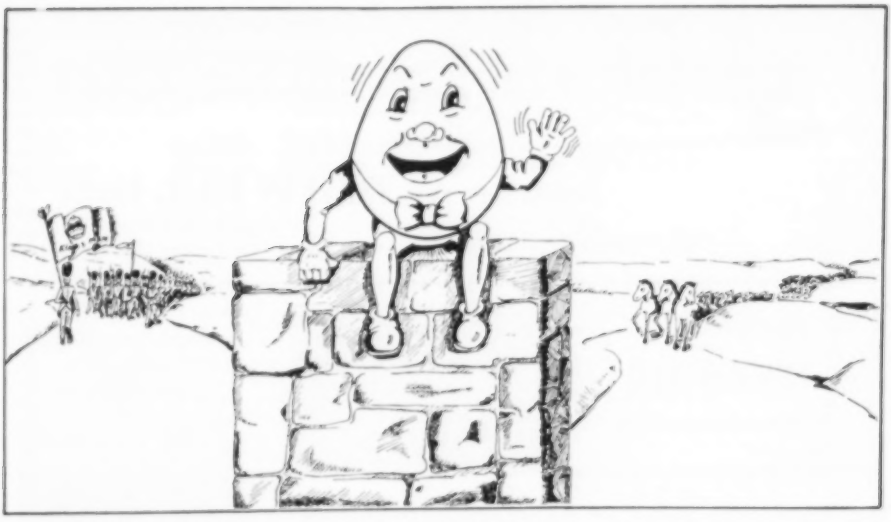

HUMPTY DUMPTY SAT ON A WALL
HUMPTY DUMPTY HAD A GREAT FALL,
ALL THE KING'S HORSES AND ALL THE KING'S MEN
COULDN'T PUT HUMPTY DUMPTY TOGETHER AGAIN.

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—By keeping the cervical vertebrae properly positioned during sleep, the Jackson CERVIPILLO prevents aggravation of symptoms commonly observed with the conventional pillow.

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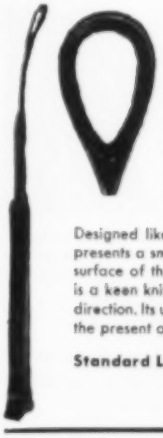

Grover Menisectome

Used through any arthrotomy exposure and on either semilunar cartilage, it guarantees the integrity of all structures within the joint and permits complete removal of either meniscus.

Designed like a large intra-uterine curette, it presents a smooth rounded guard on the outer surface of the ring, the inner margin of which is a keen knife edge permitting cutting in any direction. Its use will shorten by about one-third the present operating time.

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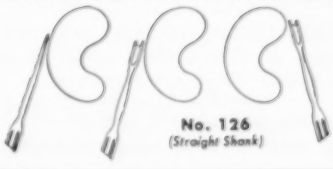
No. 108
(Curved Shank)

ILLUSTRATIONS SHOW POSITIONS OF KNIVES IN USE



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The angles of the blades and the modified handles of these retractors have been altered to give a better grip and keep the fingers away from the incision. They are exceptionally well designed for the removal of menisci and for use in practically all knee joint operations. The set of four comprises one hook and three with blade lengths from 1½ inches to 3 inches.

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5 Two-lb. Weights
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Above will fit any door. Padded to prevent marring.

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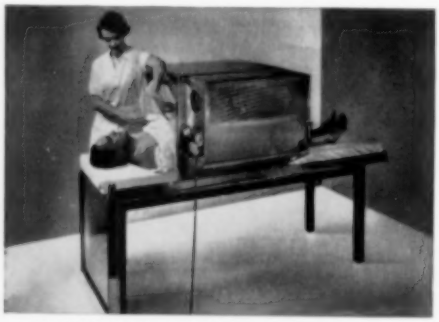

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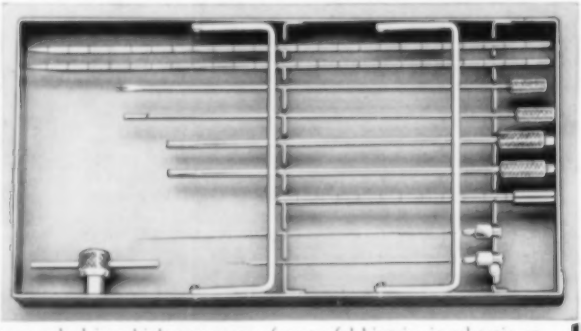

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REFERENCE: The Journal of Bone & Joint Surgery, Volume 33-A, No. 1; page 93 et al., January, 1956. As described in Armamentarium, Vol. II, No. VI.

OS-5000 — Craig Vertebral Body Biopsy Set, complete . . . **$62.50**

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[1] Jackson, Ruth. The Cervical Syndrome, Clinical Orthopaedics No. 5, 136-148, 1955.

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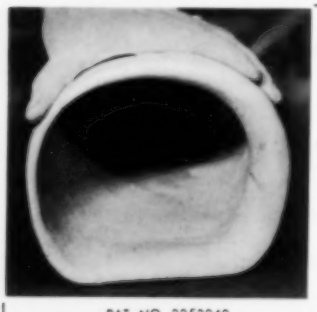

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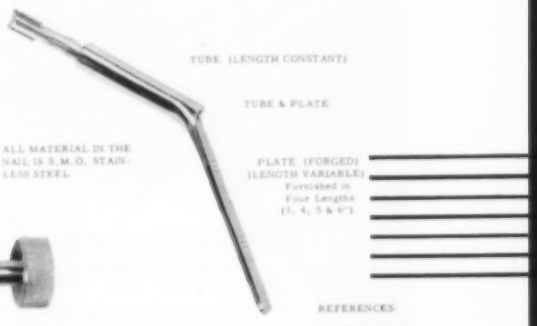
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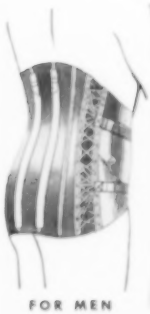
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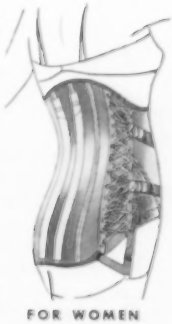
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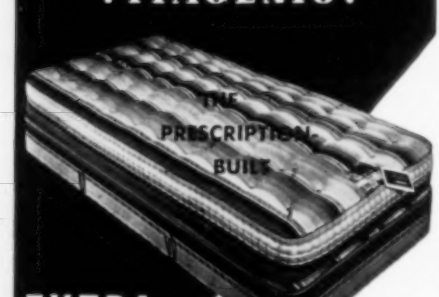

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DETACHABLE — DENNIS BROWNE TYPE

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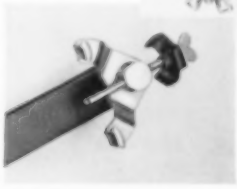

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Manufacturers of Orthopedic Appliances

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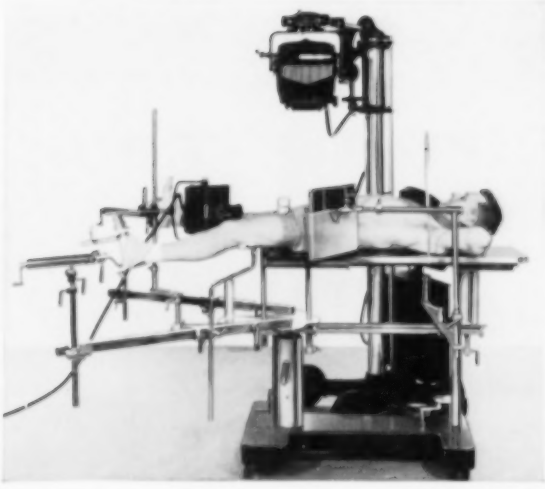
DV ORTHOPEDIC & SURGICAL TABLE



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References: 1. Hollander, J. L., *Ann. New York Acad. Sc.* **61**:511, May 27, 1955.
2. Hollander, J. L., *et al. J.A.M.A.* **158**:476, June 11, 1955.

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